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SYLLABUS

OF

COURSES OF LECTURES AND INSTRUCTION

IN

GENERAL GEOLOGY,

WITH

REFERENCES TO SOURCES OF INFORMATION.

BY ALEXANDER WINCHELL, LL. D.,
PROFESSOR OF GEOLOGY AND PALÆONTOLOGY IN THE UNIVERSITY OF MICHIGAN.

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The solid Earth whereon we tread
In tracts of fluent heat began,
And grew to seeming random forms,
And seeming prey of cyclic storms.
Till at the last arose the man."

"There rolls the deep where grew the tree.
Oh, Earth, what changes hast thou seen!
There, where the long street roars, hath been
The stillness of the central sea.

"The hills are shadows, and they flow
From form to form, and nothing stands.
They melt like mist—the solid lands
Like clouds they shape themselves and go."

In Memoriam.

Vidi ego quod fuerat quondam solidissima tellus
Esse fretum: vidi factas ex æquore terras
Et procul a pelago conchæ jacuere marinæ.

VID: *Met.*

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PREFACE.

In citing sources of information, the references are generally made first, to two standard text-books, Dana's "Manual of Geology," and Leconte's "Elements of Geology." Following these are frequent citations of other text-books and manuals, and some well-known popular works. Often the references extend to reports of original researches, especially those of American origin. It has been the aim, however, to quote few works not known to be generally accessible to the student. In a few cases, nevertheless, the references will be found sufficiently complete for advanced students. Thus, most of the important original sources are cited under the subjects of *Eozoön*, Fossil vegetation of America, Extinct American Reptiles and Extinct American Mammals.

Methods of minuter research are indicated in the "Supplement," and here are references to more recondite sources of information.

A. W.

UNIVERSITY OF MICHIGAN, October, 1879.

802015

ABBREVIATIONS.

A. A. A. S.=Proceedings of the American Association for the Advancement of Science.

Ag.: *Sk.*=L. Agassiz: Geological Sketches, Boston, 1866.

Am. Jour.=American Journal of Science and Arts, New Haven, IIId Series, unless otherwise noted.

Am. Nat.=American Naturalist, Salem, Mass., now Philadelphia.

Bakewell: *Geol.*=Bakewell: An Introduction to Geology, etc., Am. ed., 8vo., 1839.

Bul. Hayd. Sur.=Bulletin of the U. S. Geological and Geographical Survey.

Bul. Nat. Mus.=Bulletin of the U. S. National Museum.

Can. Nat.=Canadian Naturalist, Montreal.

Cook; *Geol. N. J.*—Cook: Geology of New Jersey, 1868.

Cotta: *Ore Dep.*—Cotta: Treatise on Ore Deposits, New York, 1869.

Cuvier: *Discours.*=Cuvier: Discours sur les revolutions du globe, 1828.

D.=Dana, or Dana: Manual of Geelogy, 2d ed., 1874.

Darwin: *Coral Reefs.*=Charles Darwin: Structure and Distribution of Coral Reefs.

Daws.: *Story.*=Dawson: The Story of the Earth and Man, New York, 1873.

Daws.: *Dawn.*=Dawson: The Dawn of Life, New York.

De la B.: *Obs.*=De la Béche: The Geological Observer, 2d ed., London, 1853.

Fig.: *World.*=Figuier: The World before the Deluge, London ed., 1867.

Fos. & Whit.: *L. Sup.*:=Foster & Whitney: Report on the Geology of the Lake Superior Land District, 1850-1.

Hayd.: *Rep.*=Hayden: U. S. Geological and Geographical Survey of the Territories.

Hayd. *Rep.*=Contributed to Hayden's Report.

Hux.=Huxley: The Anatomy of Vertebrated Animals, Am. ed., 1872.

King: *Rep.*=King: U. S. Geological Exploration of the Fortieth Parallel.

King *Rep.*=Contributed to King's Report.

L.=Leconte: Elements of Geology, New York, 1878.

Log.: *Geol. Can.*=Logan: Geology of Canada, 1863.

Ly.: *Man.*=Lyell: Manual of Elementary Geology, 6th ed., N. Y., 1857.

Ly.: *Prin.*=Lyell: Principles of Geology, 8th ed., 1850.

Newb., *Ives' Rep.*=Newberry in Ives's Report, upon the Colorado River of the West, 1861.

Palæont. Soc.=Transactions of the Palæontographical Society, London.

P. A. N. S.=Proceedings of the Academy of Natural Sciences, Philadelphia.

P. A. P. S.=Proceedings of the American Philosophical Society, Philadelphia.

P. B. S. N. H.=Proceedings of the Boston Society of Natural History.

Pop. Sci. Mon.=Popular Science Monthly, New York.

Pow. *Rep.*=Powell: U. S. Geographical and Geological Survey of the Rocky Mountains.

Pow. *Rep.*=Contributed to Powell's Report.

Q. J. G. S., or Quar. Jour. Geol. Soc.=Quarterly Journal of the Geological Society of London.

Récl.: *Earth*=Réclus: The Earth, etc., Am. ed., 1871.

Reg. Rep.=Appendix to the Report of the Regents of the University of the State of New York on the condition of the State Cabinet of Nat. Hist.

Rep. Coast. Surv.=Report of the United States Coast Survey.

W.=Winchell: Sketches of Creation, New York, 1870.

W.: *Geol. Mich.*=Winchell: First Biennial Report of the Progress of the Geological Survey of Mich., 1861.

W.: *G. T. Reg.*=Winchell: The Grand Traverse Region, 1866.

Wheeler *Rep.*=Contributed to Wheeler's Report, U. S. Geograpical Surveys west of the 100th meridian.

Whit.: *Met. W.*=Whitney: Metallic Wealth of the United States, 1854.

W.: *Mich.*=Winchell: Michigan, being condensed Popular Sketches of the Topography, Climate, and Geology of the State, 1873

Woodw.: *Man. Mol.*=Woodward: Manual of the Mollusca.

SYLLABUS.

PART I.

INDUCTIVE OR POSITIVE GEOLOGY.

I. OUTLOOK OF THE SUBJECT.

1. Preliminary.

1. Distiction between Facts, Doctrines and Speculations.
   - (1.) The Facts Demonstrable to the senses of all.
   - (2.) Doctrines are accepted Explanations of the Facts.
   - (3.) Speculations are explanations still under discussion—Possess various degree of plausibility.
   - (3.) Inductive or Positive Geology deals with Facts and Doctrines.

II. Geology is a History. (D. 4.)

1. History of the Planet (D. 1, 2, 3) — History of its organic occupants. (D. 2, 5.)
2. Data or Materials of the History are Relics of former conditions of the earth and its occupants. (D. 4–5.)
3. Mineral masses — Animal remains — Vegetable remains.
4. Mineralogy and Chemistry — Zoölogy — Botany.
5. The earth also an Astronomical body.
6. Its Form, Density and Movements determined by Mechanical principles — And these are Mathematical relations.
7. Geology the Science to which all other sciences are ancillary.

III. The Starting Point of Investigation.

1. Phenomena presented by a Drift-covered surface.
2. Phenomena presented by an outcrop of Stratified rocks.
   - (1.) The stratified condition — Sedimentation, Lect. VI.
   - (2.) Relics of aquatic creatures — Fossils — Paleontology.
   - (3.) Indications of marine origin.
   - (4.) Wide existence of such phenomena.

3. The phenomena presented by an outcrop of Unstratified rocks. (D. 107–8, L. 205–11.)
   (1.) Crystalline — Non-fossiliferous.
   (2.) The rocks traceable to a fissure through stratified beds. (L. 205–7.)
   (3.) Indications of igneous origin.
4. Succession in superposition of rocks.
   (1.) Often seen in a high hill or mountain slope.
   (2.) Often in traveling over a level country.
   (3.) Persistence in order of superposition.
5. Discontinuity of strata. (D. 96.)
   (1.) In consequence of erosions — Illustration.
   (2.) In consequence of non-deposition.
   (3.) Land and sea-covered areas.
   (4.) Geological sections — Illustration. (D. 148, 166.)
   (5.) Geological maps — Illustrations. (D. 144.)

IV. Determination of the Normal Series of Rocks.

1. Generalization from many observations.
2. An Ideal section of the known rocks. (Chart.)
   (1.) A graduation of rocks from top to bottom.
   (2.) Indications of successive depositions.
   (3.) Indications of progressive cooling.
   (4.) Progressive changes in organization.
   (5.) General classification of the rocks. (D. 133–43; L. 269–71.)

Aqueous or Sedimentary.	Cenozoic.	Stratified and Fossiliferous.
	Mesozoic.	
	Palæozoic.	
	Eozoic. Imperfectly stratified. Few fossils.	
Igneous or crystalline. Of all ages. No fossils.		

II. RECORDS OF PAST CONDITIONS OF THE EARTH.

I. Traces of past conditions the Material of the History.

1. Certain terrestrial changes in visible progress.
2. Similar results traceable indefinitely into the past.

II. Traces of the former action of the Sea.

1. Fossil shells far from the sea and at high altitudes.
   (1.) Ancient opinions concerning them. (Lyell: *Prin.* Bk. i, ch. iii.; Marsh. Saratoga Add. Am. Asso., 1879: Hallam: *Literature of Europe*, i., 228-30) — "Freaks of Nature"—"Plastic Power" — "Experimental Moulds" — "Fortuitous Concourse of atoms" — "The Mosaic Deluge" — "Influence of the Stars."
   (2.) They are genuine *debris* — Illustrations from the remains of shore-shells or of human industry. (W. 18–22.)
2. Sea-beaches far inland — Valley of St. Lawrence. (D. 549; Ly. *Prin.*, 178, 482; De la Bêche: *Observer*, 445-57.)
3. Changes of sea-level actually observed. (D. 582-5; L. 127; W. 19-25; De la Bêche: *Obs.*, 435-44; Réclus, 527-55, 562-7, map of upheavals and depressions.)

(1.) Scandinavia. (D. 582: L. 129; Lyell, *Prin.*, 499-511; Réclus, 531.)
(2.) Temple of Jupiter Serapis. (D. 584; Lec., 127-8; W. 19; Lyell, *Prin.*, 489.)
(3.) Old Roman roads. (Ly. *Prin.*, 493.)
(4.) Oscillations observed in America. (Cook: *Geol. N. J.*, 350-73; Dawson, *Quar. Jour. Geol. Soc.*, xi., 119; Hitchcock: *Geol. Mass.*, 307; Jackson: *Geol. N. H.*, 280; Long Island Hist. Soc., May, 1868; Rèclus, ch. lxxxiv.) — Subsidence at St. Augustine, Fla. — Elevations in Pamlico Sound — Subsidence on the coast of N. J. — In Nantucket Harbor — Elevations along the New England Coast — Rotation of Grand Manan — Rotation of Nova Scotia — Submergence of the site of Louisbourg, (Cape Breton.) — Six hundred miles of the coast of Greenland sinking for 600 years. (D. 583; L. 129; Réclus, 555.)
(5.) Sea-waves on the coast of Chili and Peru in 1590, 1730, 1751, 1822, 1835, 1837, 1868-1877. (D. 585. 662, 742; L. 130; Lyell: *Prin.*, 435, 439, 481; *Pop. Sci. Monthly*, Sup, Dec., 1877; *Rep. U. S. Coast Survey*, 1862, 1869.)
(6.) Actual emergences of new islands. (W. 23; Réclus, 489-96; Lyell: *Prin.*, 416) 425, 449) — Graham, I., 1831 — Sabrina in the Azores, (De la Beche: *Obs.* 100-1) — Santorin, (De la Beche: *Obs.*, 391-7.) — Aleutians, 1806, 1814 — In the Pacific. (D. 84) — Conjecture concerning the Symplegades.
(7.) Effects of a moderate depression in Illinois. (Bannister: *Geol. Ill.*. iii., 241,)

III. Traces of the former action of Heat.

1. Baked sandstones, limestones and shales.
2. Refrigerated molten rocks. — In western U. S. (L. 207; King i., 545-677; Gilbert in *Wheeler Rep.* iii., 118-131, 525-41; Howell in *id.*, 297; Stevenson in *id.*, 411-25; King, *Am. Nat.*, xi., 459. See further Lect. XXVI.)
3. Some traces of fire older than those of water.

IV. Unextinguished Fires. (D. 699.)

1. Volcanoes. (D. 702-16; L. 81-93; Ly., *Prin.*, 526-32; De la Bêche, *Observ.*, 317-48; Bakewell: *Geol.*, 311-44; Réclus, 419-52; 458-74; See further Lect. XXVI.)
2. Hot springs. (D. 692; Ly. *Prin.*, 238-49; Gilbert, *Wheeler Rep.*, iii., 150 [136 localities in U. S.]: Hayden, *Ann. Rep.*, 1871, 64-198 [Geysers]; Bakewell, *Geol.*, 443, 447-50; Réclus, 234-7. See further, Lect. XXVI.)
3. Mines and tunnels. (*Nature*, 3 Apr., 1879, 510) — Mont Cenis (Matthew, *Canad. Nat.*, vi., 96) — St. Gothard (*Geol. Rep., Italy*, 1873, *Nature*, 30 Jan. 1879, 303) — On the Comstock lode (Church, *Am. Jour.*, xvii., 289) — Sutro tunnel, *N. Y. Daily Tribune*, 6 Sept. 1879, diagrams.)
4. Artesian borings. (D. 699; Ly. *Prin.*, 236; De la Bêche: *Obs.*, 463-7 Réclus, 233, 480-8) — Alabama (W. *Proc. Am. Asso.*, 1856 — St. Louis (Litton: *Trans. St. Louis Acad.*, i., 84; Brodhead: *Mo. Geol. Rep.*, 34) — Sperenberg (*Nature*, 11 Jan., 1877.)

V. Foundation Stones of the Land. — Granites, Gneisses, and other rocks bearing marks of fire. (Lect. III.)

VI. Records of Extinct Populations. (Lects. IV.–XVII.)

III. THE OLDEST KNOWN ROCKS.

On Rocks, see Von Cotta: *Rocks classified and described*, London ed., 1866; Blum: *Handbuch der Lithologie und Gesteinlehre*, Erlangen, 1860; Brooks: *Geology of Iron Region of Mich.* in *Geology of Mich.*, i, chap. iii.-iv.; Julien, in *Geol. of Mich.*, ii.; Hawes in Hitchcock's *Geol. of N. H.*, pt. iv., Mineralogy and Lithology, in vol. iii.; Foster and Whitney: *Geology of Lake Superior Land District;* Zirkel: *Lehrbuch der Petrographie*, Bonn, 1866, 2 vols., 8vo,; Zirkel: *Die Mikroskopische Beschaffenheit der Mineralien und Gesteine*, Leipzig, 1873, 8vo.; Rosenbusch: *Mikroskopische Physiographie der Mineralien und Gesteine. Ein Hulfsmittel bei mikroskopischen Gesteinstudien.* Stuttgart, 1873, 2 vols., 8vo.

I. Earliest Rocks on a cooling Planet.

1. Hypothesis of a fire-formed crust. (D. 146-7.)

1. Commencement of sedimentation. (D. 147.)
   - (1.) Implies a cooled rock-surface and an ocean. (D. 147.)
   - (2.) Chemical Precipitation in Primeval Ocean. (D. 147; W. 60-1; Hunt: *Chem. and Geol. Essays, iid paper*)
   - (3.) Vast accumulation of stratified materials. (D 147.)
3. Cause of disappearance of fire-formed crust.
   - (1.) The Isogeothermal plane.
   - (2.) Ascent of isogeothermal planes as sediments accumulate.
   - (3.) Progressive Melting or softening of under surface of crust.
   - (4.) Progressive Metamorphism at higher levels.

II. Classification and thickness of Archæan rocks. (D. 140, 146; Hitchcock: *Geol. N. H.*, ii., 468; Hunt: *Chem. and Geol. Essays.*

ARCHÆAN	Eozoic.	Huronian.	Upper. / Lower.	20,000 feet.
		Labradorian,	10,000	30,000 feet.
		Laurentian,	20,000	
	Pyrolithic (Hypothetical.)			

[A "Montalban" series is placed by T. S. Hunt above the Huronian, and by C. H. Hitchcock below the Labradorian.]

III. Surface exposures of Archæan Rocks.

1. The Fundamental Rocks everywhere.
2. The great nuclear area in British America, and its appendages in N. Y., Mich., and Wis. (D. 150, 160; W. 74; Daws.: *Dawn*, 7, 8; Foster and Whitney: *L. Sup.*, Pt. ii., 8; Irving: *Geol. Wis.*, 1877, 461-524.)
3. The Appalachian system of areas. (D. 150.)
4. Trans-Mississippi exposures. (King i., 15-98. See also Lects. XXIII., XXIV., XXV.

IV. Kinds of Rocks.

1. Laurentian predominantly granitoid, of both micaceous and hornblende series. (D. 151, 67-70.) — Also crystalline limestones. (D. 151; Logan: *Geol. Can.*, 1863). — Iron ores. (Perhaps those of Mich., D. 151, 159. See below.) — Graphite. (D. 151, 152; Logan: *Geol. Can.*, ch. iii. and 586-93; Daws.: *Dawn*, 18, 27-33. See also general references above.)
2. Huronian predominantly quartzose. Also diorites, limestones, iron and copper ores. (D. 159; Logan: *Geol. Can.*, ch. iv., and 594-6; 572-87; Brooks in *Geol. Mich.*, p. 1-319; Pumpelly, *Geol, Mo.*, 31-214; Moore, in *Geol. Mo.*, 1874, 638-71.)
3. Richness in Minerals. (D. 151-2.)

V. Condition of the Strata.

1. Highly disturbed. (D. 153; L. 272-3.) — Sections. (D. 148, 153; L. 273; Hitchcock: *Geol. N. H.*, ii., 15-36; King, i., Diagr., pl. i.; ch. ii., pl. ii., and Atlas, Map I., sections; Brooks: *Geol. of Mich.*, i., 184; Daws.: *Dawn*, 13; Campbell: *Am. Jour.*, xviii., 19, 121, showing relations of newer rocks.)
2. Metamorphic — Explanation. (D. 724; Bischof: *Chemical Geology;* Daubrée: *Études synthetiques de Géologie expérimentale;* Hunt: *Chemical and Geological Essays.*)
3. Subjected to enormous denudation. (Lects. XXVIII., XXIV. XXVII.)

IV. THE DAWN OF LIFE.

Dawson: The Dawn of Life.

I. A hypothetical Protophytic period.

1. A strictly inorganic period must have existed. (D. 146.)
2. Mutual dependence of the kingdoms of life.
3. The vegetable the necessary forerunner of the animal.
4. Geological indications of early Laurentian vegetation.

II. Remains supposed Organic in Laurentian strata. Daws., as above.)

1. These strata once known as "Azoic." (Foster & Whitney: *Geol. Lake Sup.*, pt. ii., 8.)
2. Suspicions based on iron-ores and graphites. (Hunt: *Am. Jour.*, II., xxv., 431; Dawson: *Dawn*, 24-7.) — A deductive discovery as in exact science.
3. Organisms found Oct. 1858. (Logan: *Canad. Nat.*, iv., 300; *Geol. Can.*, 49; *Quar. Jour. Geol. Soc.*, Feb. 1860; W. 435-7.)

(1.) Stratigraphical position. (D. 158.) — Mineral Associations. (Daws.: 113-26; Hoffman: *Am. Jour. Sci.*, i., 378; *Jour. f. prakt. Chemie*, May, 1869.)

(2.) *Eozoon canadense* as found — Description and illustrations. (D. 158: L. 275; W. 68; Daws.: *Dawn*, 59-93.

(4.) Its zoölogical affinities. Dawson and Carpenter: *Quar. Jour. Geol., Soc.*, Feb., 1865: Daws.: *Dawn*, 59-93 — *Amœba* and *Actinophrys*. (W.. 70; Daws.: *Dawn* 60) — Compare Stromatoporidæ. (W. *Proc. Am. Asso.*, 1866.)

(4.) Its mode of Life. (Daws.: *Dawn*, 69-71.)

4. Foraminifera in all ages. (D. 131, 460, 471; Daws.: *Davon.*, 62-5, 72-6.—Their work in building up the continents. (D. 512; Daws.: *Story*, 241-3; Fig.: *World*, 241-4) — Nummulites and their structure. (D. 131, 515.) — Nummulitic limestone of the Pyramids. (D. 512; L. 485) — *Orbitoides* in America. (Daws.: *Story*, 241.)

5. Organic Nature of *Eozoön* questioned — King and Rowney. (*Quar. Jour. Geol. Soc.*, Aug., 1866; *Am. Jour. Sci.*, II., xliv., 375; *Proc. Royal Irish Acad.*, July, 1869, and Jan. and Apr., 1871; *Am. Jour.*, i., 68, 138-42; ii., 211-5.) — Burbank (*Proc. Am. Assoc.*, 1871, 262-6) — Carter. ( ) — Otto Hahn. (cited *Am. Jour. Sci.*, June, 1872, 492)—Karl Möbius. (*Palæontographica*, 1878, vol. xxv., Republished separately: see account in *Nature*, 17 and 24 July, 1879. See also Möbius in *Am. Jour. Sci.*, xviii., 177, Sep. 1879) — Otto Kuntze. (*Nature*, 28 Aug., 1879.)

6. All objections promptly met. (*Quar. Jour. Geol. Soc.*, Aug., 1866: Carpenter: *Proc. Roy. Soc.*, No. xciii., 503; Hunt: *Proc. Roy. Irish Acad.*, July 12, 1869; Carpenter: *Ann. Nat. Hist.*, June, 1874; Daws.: *Dawn*, 169-206; *Am. Jour.*, xvii., 196, March, 1879; Carpenter and Dawson: *Nature*, 31 July, 1879.

III. Conditions of Land and Water when Eozoon appeared.

1. No positive evidence of land. — But the Laurentian rocks are partly fragmental.

2. The sea still in a tempestuous state.

IV. A long pause through the Huronian Age.—Probable future discoveries — Supposed foreign equivalents.

V. GEOLOGICAL CLASSIFICATION.

I. Two Geological Conceptions, Time and Events.

1. Events or results of geological activity.

(4.) Among the Rocks: — They differ in Constitution. — Silicious, Aluminous and Calcareous. (D. 65; Lyell: *Man.*, 11-12.) — They differ in relations of Position. Unconformability. (D. 100.) — This implies changes of level of sea-bottom. — Marks boundary line in succession of deposits. (L. 269.)

(2.) Among the Fossils: — Progressive change. — Sudden transitions. — Generally corresponds with unconformability. (King: *Am. Nat.*, xi., 469.) — Transitions graduated by new discoveries. — Have cataclysms occurred? (Cuvier: *Discours;* Lyell: *Prin.*) — The truth lies between the cataclysmic, and the uniformitarian theories. (King: *Am. Nat.*, xi., 461-70; L. 288, 317, 333, 495.)

2. Time — Marked off by events — Greater and less divisions of time — Corresponding significance of the events.

II. Terms employed.

1. Rocks:—Layer, Stratum, Formation. — Formations arranged in Sub-groups or Stages, Groups, Systems and Great Systems.

2. Time: — Arranged in Epochs, Periods, Ages and Times or Æons.

3. Correlation of terms in relation to Rocks and Time.

In reference to Time.	In reference to Rocks.	Examples.
TIMES or ÆONS.	GREAT SYSTEMS.	Eozoic, Palæozoic.
AGES.	SYSTEMS.	Laurentian, Silurian.
Periods.	Groups.	Primordial, Canadian.
Epochs.	Stages.	Acadian, Potsdam.

4. Geographical origin of proper names.

III. General Historical Classification of Rocks and Geological Time. (D 140; L. 201; W. 437-8, and *Geol. Chart*; Marsh: *Am. Jour.*, xvi., pl. iv. — European Equivalents. (Cope, *Bulletin Hayden Survey*, v. 50-1; W.: *Geol. Chart.*)

IV. Intrusive Rocks. — Veins. (D. 108; L. 225-39; Whitney: *Metallic Wealth U. S.*; v. Cotta: *Ore Deposits.*) — Dikes. (D. 109, 111.) — Faulting. (D. 111; L. 222-5. See further Lect. XXVI.)

VI. SEDIMENTATION.

De La Beche: *Geological Observer*, chaps. v., vi., and vii.; Dana: *Manual*, 649, 665-674.

I. Constitution of Sediments

1. Chemical Precipitation. (De la Beche: *Obs.*, 102-111; Bischof: *Chemical Geology.*

(1.) Most active in primeval ocean. — Sketch of reactions. (W. 59-61.)

(2.) Always in progress to some extent. — Submarine emanations. — Certain mineral springs. — Evaporation. (De la Beche, 106.)

(3.) Mostly calcareous. — Often gypseous and saline. — In the primitive sea partly aluminous and silicious.

2. Organic Deposits. (De la Bèche, 112-64; D. 59-62, 606–626.)

(1.) In bulk. (D. 614.) — Exuviæ of molluscs. L. 153,) — Foraminifera. (D. 477, 671; L. 453-4; Bailey, *Smithsonian Contributions*, ii., and *Am. Jour.* II., xvii., 176, xxii., 282; Pourtales: *Trans. Am. Asso.*, 1850., 84, and *Rep. Coast Survey*, 1853, 1858, Letter to Prof. Bache, 17 May, 1862.) — Vitalized stony growths. — Corals. (D. 59, 617-26; L. 138-53; Dana: *Corals and Coral Islands.*)

3. Pulverized. — About reefs. — Disintegrated exuviæ. (D. 615, 621.)

3. Fragmental deposits. (D. 667.)
   (1.) Of Littoral origin. (D. 647; L. 31, 36.)
   (2.) Of Fluviatile origin. (D. 647; L. 20, 22.]

II. Cementing Materials. — Carbonate of lime. (D. 692.) — Silica. (D. 693, 725.) — Oxyd of iron. (D. 695.)

III. Coloring Materials, — Yellow, red and black iron oxyds. — Iron silicate. — Maganese. (D. 759.)

IV. Sediments in relation to Distance from Shore.

1. Littoral deposits coarser.
2. Deep-water deposits finer. (L. 40.) — Diminished in volume.
3. Deep-water deposits often calcareous. (D. 671.)
4. Local variations in the same sheet of sediments. (D. 80, 666-7. — Conglomerates, sandstones, aluminous sandstones, shales, calcareous shales, limestones. (D. 667, 669-72.) — Cross-bedding, (D. 82, 83; Hayden, *Rep.*, 1874, pl., vi,) — These variations well illustrated in North America. (D. 670, 671, *et passim.*)
5. Effect of slow submergence or emergence. — Extension of littoral deposits. (D. 672-3.)

V. The Sedimentary Cycle. (W. 133-6, 1870; Newb.: *Geol. O.*, ii., 82-3, 1874; *Proc. A. A. A. S.*, 1874, 185-96; Edward Hull: *Q. Jour. G. S.*, xviii., 127-46, 1862; *Geol. Mag.*, v. 143; *Quar. Jour Sci.*, vi., 353; Dawson: *Q. J. G. S.*, xxii., 101-3, 1865; *Acadian Geol.*, 135; *Address before Nat. Hist. Soc.*, Montreal, 1865; Compare Hunt: *Geol. Can.*, 1863, 576-8; *Am. Jour. Sci.*, II., xxxv., 1863, 167; Eaton: *Geol. Text Book*, 1832, and *Am. Jour.*, II., xxiii., 281; Worthen: *Geol. Ill.*, i., 112-3, 1866.

1. Graduated intensity of action through each period.
2. Deposits graduated accordingly. — Coarse Fragmental, Fine Fragmental, Calcareous, Calcareo-fragmental. (D. 80.)
3. Each system and group presents a cycle of sediments. — Illustrate. (W. 134.)
4. Prominence of the Limestone mass in each cycle. — This a conspicuous landmark for identification, (W. 135-6.)

VII. THE REIGN OF TRILOBITES, OR THE LOWER SILURIAN AGE.

See official Geological Reports, especially those of New York, Ohio, Illinois, Canada. Murchison: *The Silurian System*, and *Siluria*.

On the general subject of Palæontology see NICHOLSON: *Manual of Palæontology*, and PICTET: *Paleontologie*, 4 vols. and Atlas of 110 plates.

For list of lower Silurian Fossils, see Miller: *The American Palæozoic Fossils*, 1877; Bigsby: *Thesaurus Siluricus*, 1868.

For complete bibliography, see C. A. White's, *Bibliography of North American Invertebrate Palæontology*, 1878, Hayden Survey, "Miscellaneous Publications;" No. 10, 1878, and *Supplement* to Bibliography, from "Bulletin" of the Survey, vol. 5, No. 1, 28 Feb. 1879.

I. **Lower Silurian Rocks.**

1. General aspect. — Mineral constitution and condition.
2. Relations to the Eozoic. (L. 281.) — Unconformability. — Sections. (D. 166; W. 84; L. 277; Campbell: *Am. Jour. Sci.*, xviii., 19, 121.)
3. Groups:—Primordial, Canadian and Trenton. (D. 163.) — Place of the Galena limestone. (D. 196, 197.)
4. Exposures:—(1.) St. Johns, N. B. Georgia, Vt.; Braintree, Mass.; Minn.; Wis.; Lake Superior. (W. 82-93; Foster and Whitney; *Geol. L. Sup.*; Brooks; *Geol. Mich.*; Black Hills, Dak. (N. H. Winchell: *Ludlow's Rep. on Black Hills*, 1874, 63-4, and Geol. Map.
   (2.) Cincinnati, O.; Richmond, Ind.; Lexington and Frankfort, Ky.
   (3.) Nashville, Tenn. (Geol. Tenn.)
   (4.) St. Joseph's I.; Little Bay de Noquet, etc., Mich. (W.: *Mich.*, 50.)
   (5.) St. Anthony's Falls, Minn. (N. H. Winchell: *Geol. Rep. Minn.*)
   (6.) Trenton Falls, N. Y.; Watertown, Potsdam, etc., N. Y.
5. Sections:—New York. (D. 16; Hall: *Geol. N. Y.*, 4th Dist. 27.) — Canada. (*Geol. Can.*, 847.) — Virginia. (Campbell. *Am. Jour.*, xviii., 19, 121.) — Rocky Mountains. (King: *Geol. 40th Parallel*, Atlas Map I., and "General Sections.") — Wisconsin. (Hall: *Geol. Wis.*, Plate III.; Chamberlin: *Geol. Wis.*, 1876, Atlas, Pl. XI. — Pennsylvania. (Rogers: *Geol. Penn.*, ii., 894, and Atlas, Sheet i.)
6. Economical products. (Whitney in *Geol. Io.*, 1858, i., 422-71; Brodhead: *Geol. Mo.*, 1874, 503-637; Whitney: *Wis. Geol. Rep.*, 1862, 221-420; Strong: *Wis. Rep.*, 1877, 689-752.)

II **Lower Silurian Times.** — The treeless shore. — The shelving Beach. (Ag. *Geol. Sk.*, 36.) — Its fucoidal imprints. — Its sands and ripple marks. — A shallow sea with a sinking bottom. — Another sea covering the "Great Basin."

III. **Lower Silurian Life.** (Reports cited above. Also Billings: *Palæozoic Fossils of Canada*, 1865.

1. Sudden exuberance of life. (Ag.: *Geol. Sk.*, 37.) — A busy population. (Daws.: *Story*, 40, 66, views.)
2. The type of Trilobites, with illustrations. (D. 174-5; L. 309; Daws.: *Story*, 44-5; Barrande: *Système Silurien*, vol. i.) — General structure, rank and affinities. — Historical development and decline. — Their suddenness and zoölogical rank to be noted. (See especially Barrande: *Système Silurien du centre de la Bohême*

Tome i., and *Trilobites*, 1871, abstracted in W.: *The Doctrine of Evolution*, Appendix.)

3. The Type of Chambered Shells. (D. 124; L. 305-8; Barrande: *op. cit.*, ii., and *Distribution des Céphalopodes Siluriens.* — General structure, rank and affinities. (W.: 110-21.) — Permutations of *septum*, *siphon*, and *mode of enrollment.* (W. 119.) — Glimpse of the later history of the type. — Later than trilobites, but inferior.
4. The type of crinoids. (D. 128; L. 297-300; Billings in *Can. Geol. Surv.*, Decades iii. and iv. — General structure, rank and affinities.
5. Corals and Graptolites. (D. 199.) No polyp corals till the VIth epoch of life or Trenton. — Graptolites. (Hall, *Canad. Geol. Surv.*, Decade ii.)
6. Lingulidæ and their relations. (L. 301; Daws.: *Story*, 41-3.) — Persistence of type. — Discina.

IV. Events which terminated the Lower Silurian Age. — Uplift of Green Mts. (D. 212-16.) — The Cincinnati Axis. Newberry: *Geol. of O.*, i., 93-111; Cox: *Geol. Ind.*, 1879, 5 *seq.*

VIII. THE REIGN OF MOLLUSCS, OR THE UPPER SILURIAN AGE.

Official Geological Reports, especially those of New York, Ohio, Illinois, Michigan and Canada. Also the other references under Lect. VII.

I. How each act of the Drama was closed.

1. Premonitory tremblings. — Progressive change of sea-bottom. — Obliteration of life. — Uplift of a new belt of land.
2. Such movements generally slow. — But sometimes violent.
3. Changes of systemic value world-wide. — Perhaps not synchronous in remote regions. (D. 192.) — Minor changes progressively more local.

II. The lands of later Silurian time. — The desolate and wasting continent. — The winding shore. (D. 250-1.) — The eroding waves. — The teeming sea. — Scenes. (Fig.: *World*, 93; Daws.: *Story*, 40, 66.)

III. Organization in later Silurian time.

1. The perpetuated Trilobites, Orthoceratites and Crinoids. — Specimens. (D. 227.)
2. The type of Polyps, or true Coral-animals. (D. 617-26; ***Corals and Coral Islands; Zoöphytes,*** **Wilkes Expl. Exped.)**

(1.) The zoölogical position of Polyps. (D. 130.)
(2.) Actinoid Polyps. (D. 130.)
(3.) Coral secretions. — Coral structures. (D. 617: L. 138-53.) — Coral reefs and islands. (D. 618-26; L. 139; De la Beche: *Observer*, 165-205; Darwin: *Coral reefs;* Beete Jukes: *Surveying Voyage of the Fly;* Reclus: *Earth*, 556-61.)
(4.) Upper Silurian Corals. — Favositidæ. — Halysites. (D. 225; L. 293.)

3. Other coral secreting animals. (D. 130.)
4. *Orthidæ.* (D. 170-2.) — *Eurypterus.* (D. 239; L. 313; Fig.: *World*, 99.)

IV. Upper Silurian Rocks.

1. Illustrative sections. (Lect. VII., I., 5.)
2. The great limestone mass of this age. — Western New York, (D. 218.) — Drummond's Island. (W.: *Geol. Mich.*, 55: *Michigan*, 52.) — Big Bay de Noquet. (W.: *Mich.*, 53.) — Chicago. (Worthen: *Geol. of Ill.*, 129-36; Winchell and Marcy, *Mem. Bos. Soc. Nat. Hist.*, 4to., No. 2.) — Southern Ohio and Ind. (D. 221; Newb.: *Geol. O.*, iii., 7.)
3. Noteworthy Erosions. — Niagara River. (D. 219; W. 244. See Lects. XX. and XXVII.) — The Northern Lakes. (Newb.: *Geol. O.*, ii., 72-80; iii., 45-51; W. 220; Foster and Whitney: *Geol. L. Sup. Land. Dist.*)

V. Chapters of Upper Silurian History.

1. Niagara, Salina, Lower Hederberg and Oriskany. — But the Oriskany perhaps Devonian. (D. 241.)
2. Characteristic outcrops of each group.
5. Economical products of each. (D. 220, 222, 234; Foster and Whitney: *Lake Sup.*, ii., 201.)

IX. THE REIGN OF POLYPS, OR THE DEVONIAN AGE.

Official Geological Reports, especially those of New York, Ohio, Michigan, Illinois, and Canada. Also the other references under Lect. VII. On extinct organic types, see Nicholson: *Manual of Palæontology;* Pictet: *Paleontologie*, 4 vol., Atlas, 110 plates.

I. A culmination of Polyp-life.

1. Devonian coral-reefs. (D. 225; W.: *Grand. Trav. Reg.*, 41; Ly.: *Travels*, 2d vis., ii., 203.)
2. Favositidæ and Syringoporidæ in particular. (D. 204, 259; L. 293, 319.)
3. Cyathophyllidæ in particular. (D. 255, 259; L. 292. — Ancient and modern types. (Lyell: *El.*, 403.)

II. Trilobites and Orthoceratites declining. (Daws.: *Story*, 93.)

1. Representative species.
2. *Gomphoceras, Lituites, Cyrtoceras and Clymenia.*

3. Advent of Insects and Land Plants. (D. 258; L. 315-8; Daws.: *Story*, 101-8.)

III. The advent of Vertebrate life.

1. Organization hitherto invertebrate.
2. The law of progress.
3. Realization of a new fundamental conception. — Destined to a wonderful expansion.
4. Fishes of the Old Red Sandstone. (D. 285; L. 323-4; Fig.: *World*, 110-1; Hugh Miller: *Old Red Sandstone*, etc.; Lancaster and Powrie; *Palæont. Soc.*, 1870-1; Lyell: *El.*, 415-9.)
5. Devonian Fishes of Ohio and Canada. (D. 261-5; L. 325-7; W. 120, 127; Newb.: *Geol. O.*, Pal. i., sec. ii., 247-324; *Bulletin. Nat. Inst.*, 1857, 1-8; *Am. Jour. Sci.*, xxxiv., July, 1862.)

(1.) Their systematic position. (Newb.: *Pal. O.*, i., 247-52. — Nearest living allies (L. 327-9; Newb.: *Pal. O.*, 254-5; W. 120.)

(2.) Their bulk, organization and defences. (Newb.: *Geol.O. Pal.* i., sec. ii., 247-324.)

(3.) Many of their characters relatively embryonic. (L. 331. — Cartilaginous skeleton. — Heterocercal tail. (L.330.) — Subcephalic position of mouth. — In Placoids still other characters.

IV. Growing Continents and meagre Forest coverings.

1. Glimpse of the coming age. — Flowerless land-plants. (D. 268-71; Daws.: *Story*, 102-7; *Acadian Geol.*, 2d. ed.; *Geol. Canada*, 1871; *Q. Jour. Geol. Soc.*, xv., 483, xviii., 296, xix., 458, xxvii., 270. See also general references Lect. XIII.) — Scenes. (Fig.; *World*, 106; Daws.: *Story*, 88, 103; W. 130.)
2. Relics found in New York, Ohio and Canada. (See references under IV., 1.)

V. Chapters of Devonian History.

1. Corniferous, Hamilton, Chemung. — Oriskany perhaps belongs at bottom. (See Lect. VIII.)
2. Lithological and Palæontological distinctions.
3. The great limestone axis, Cornifero-Hamilton. — The cycle of deposition well illustrated.

VI. Geographical distribution of Outcrops.

1. Syracuse, Caledonia, Eighteen Mile Creek, and all southern N. Y. — London, Goderich, Ont. — Mackinac. (W.*Mich.*, 58; Foster and Whit.: *L. Sup.*, 164-5.) — Little Traverse Bay. (W. *Grand Traverse Region*, 40-8.) — Thunder Bay, Monroe, Mich. — Columbus, Delaware, Sandusky, O. (*Geol. O.*, i., 142-9.) — Falls of the Ohio. (D. 255.)
2. Some illustrative sections. (Rogers: *Geol. Penn.*, i., and ii., 894, 895, Atlas, Sheet 1.)

X. THE REIGN OF FISHES, OR THE CARBONIFEROUS AGE.

Official reports, especially those of Ohio, Illinois, Iowa, Kentucky, Tennessee, Indiana, Michigan, Pennsylvania, and those directed by Hayden, King, Wheeler and Powell. (See Partial List of Authorities under "Abbreviations.")

See also the other General references under Lect. VII.

I. **The Waverly Period.** (W.: *The Marshall Group*, 1870, from *Proc. Am. Phil. Soc.;* also *Am. Jour.*, II., xxxiii., 352; *ib.*, xxxv., 61; *Proc. Acad. Nat. Sci.*, Phil., Sept., 1862, 405; *ib.*, Jan., 1863, 2; *ib.*, July, 1865; *Geol. Tenn.*, 1869, 364-5, 440; Meek and Worthen: *Am. Jour. Sci.*, II., xxxii., 167-177, July, 1861.)

1. The Rocks.
   (1.) Lithological variations. (W. *Proc. Am. Phil. Soc.*, xi., 73-7.)
   (2.) Geographical distribution and outcrops. (W. *Am. Phil. Soc.*, xi., 77-82.)
2. The Fossil Remains. (W. *Proc. Am. Phil. Soc.*, xii., 385-407; White and Whitfield, *Proc. Boston Soc. Nat. Hist.*, Feb., 1862, 289-306.)
   (1.) Great development of Lamellibranchs.
      (*a.*) Their zoölogical relations. (D. 125-6; Woodward: *Man. Mol.*)
      (*b.*) Their increase with the diminution of Brachiopods. (L. 303.)
   (2.) Advent of Carboniferous types. (W. *Proc. Am. Phil. Soc.*, xii, 401-7.) — Carboniferous Crinoids. (Hall, xvii. *Reg. Rep.*)
3. Questions of Parallelism.
   (1.) Sketch of history of opinion. (W. *Proc. Am. Phil. Soc.*, xi, 57-73.)
   (2.) Nomenclature and equivalences in America. (W. *Am. Phil. Soc.*, xi, 73-82; xii, 387-401, 415.)
   (3.) Comparison with upper member of Old Red Sandstone. (W. *Am. Jour. Sci.*, xxv., 61; *Proc. Am. Phil. Soc.*, xii, 412-14.)

II. **The Carboniferous Limestone Period.**

1. A season of deep and quiet waters in the West. (D. 304-5.) — Limestone mass — Eastern equivalents. (D. 293, 295, 305.) Gypsum formation sometimes constituting the base. (D. 295, 296; W.: *Geol. of Mich.* 1861.) — The "Mountain Limestone" of Europe. (D. 306.) — Perhaps embraces the Waverly of America.
2. Crinoidal life at its Culmination (D. 297-8; L. 382-3. See Geol. Reps. Ill., Iowa, Mo., Ohio.)
   (1.) Zoölogical description of Crinoids. (D. 176, 128-9: Billings: *Geol. Can.*, Decade iv., 7-17; *Am., J. S.*, II., xlvii-l.; C. A. White, *Bost. Jour. Nat. Hist.*, Jan., 1863, 481-506.)
   (2.) Their Geological history. — Living representatives.
   (3.) Abundant remains in Mississippi Valley. — Burlington, Io. (D. 303; Lyon and Cassiday: *Am. Jour. Sci.*, xxix, 68-79.) — Kentucky. (Last ref.; Lyon, *Trans. Acad. Sci. St. Louis*, i, 628-34; *Proc. Acad. N. S. Phil.*, Dec., 1861, 409-14.)
   (4.) Other forms of life. — Large Spirifers. (D. 300; Lec. 384; *Geol. Reps. Ill., Io., etc.* — Nautili. (*Geol. Reps.*) — Goniatites. (L. 386.) — Their structure and affinities. — Fishes. (D. 301; L. 389; *Geol. Ill.*, ii, 11-134; iv. 387-74 vi. 245-488; Newberry, *Geol. O., Pal.* i. 325-55.)

3. Oscillations of Level. (D. 305, 309.) — Successive epochs of deposition. (D. 294; Hall, *Geol. Iowa*, i. 92-119; *Proc. Amer. Assoc.* 1856, pt. ii., 51.)

III. The Coal Period.

1. Its characteristic the development of land-vegetation.
2. The "False Coal Measures." (D. 295.) — The "Conglomerate" or Millstone Grit. (D. 311.) — The Coal Measures. (D. 311.) — The last replaced by limestones in the far West. (D. 296.) — Meaning of this fact.
3. The Coal Fields of North America. (D. 291-3, 319-21; L. 338-9; Macfarlane: *The Coal Regions of America.* See further, Lecture XI.)
4. Progressive upward movement of sea-bottom implied by the wide-spread Conglomerate. (D. 311, 320, 354, 394, 672.)

IV. The Permian Period. — An appendix to the Coal Measures. (Meek & Hayden, *Trans. Albany Institute*, 2 March, 1858.) — Rocks, fossils and localities. (D. 367; L. 400-4; Fig: *World*, 151-63.)

XI. COAL AND COAL MAKING.

MACFARLANE: *The Coal Regions of America*, 1873; TAYLOR: *Statistics of Coal*, 1855; JOHNSON: *Report to Congress on Coals*, 1844; LESLEY: *Coal and its Topography;* Article "Coal" in *New American Cyclopædia.*

I. Great phytogenic periods of the world's history.

1. Præzoic — Only deductively known.
2. Laurentian — Graphite in Siberia, Greenland, Canada, United States, Bavaria, Norway, Sweden. (Daws.: *Dawn of Life*, 27-33; *Jour. Geol. Soc., London, Feb.*, 1870.)
3. Coal Measures of Carboniferous time.
4. Permian: — Russia. (D. 370.) — Australia. (D. 370, and *Geol. Rep.*, Wilkes, *Expl. Exped.*, 1849; L. 415.)
5. Triassic:—Richmond, Va., etc. (D. 404, 406; L. 445; Lyell: *Travels*, 2d visit, ii.)
6. Jurassic:—India and China. (L. 415; Pumpelly, Smith. Contrib. xv., Art. iv.) — Lota, SW. coast of S. Amer. (L. Ag.: N. Y. Tribune, and *Am. Jour.*, iv. 143.)
7. Cretaceous:—Rocky Mts. (D. 457. Compare, however, D. 491, 493.; L. 455-6.) — Age of the Western Lignitic or Laramie formation in dispute. (See Lect. XIV.) — Winnipeg. — Vancouver. (D. 458; Whiteaves: *Mesozoic Fossils*, i, pt. ii., Geol. Sur. of Canada, 179-90.) — Queen Charlotte's islands. (Whiteaves, *Ib.*, pt. i., 86-92.) — Monte Diablo, Cal. (Whitney, *Geol. Cal.* i., 27-31.)

8. Miocene:—Coos Bay, Or. (Newb.: *Bost. Jour. Nat. Hist.* vii., 506; Lesqx.: *Am. Jour. Sci.* II. xxvii., 359; Heer, *ib.* xxviii., 85.) — Qu'Appelle and North Saskatchewan rivers, B. A. (Hector, *Quar. Jour. Geol. Soc. Lond.*, xvii., pt. i., 409, etc.) — Europe.
9. Modern:—Peat-beds of Ireland, Denmark, Bavaria, United States and elsewhere. (D. 616; L. 133-6.)
10. Deposits of bituminous and coaly shales. (D. 66.)

II. Varieties of Coal and Carbonaceous deposits. (D. 314-7; *System of Mineralogy*, 755-5; Rogers: *Geol. Penn.* ii.)

1. Caused by pressure, heat, impurities, redeposition and chemical changes.
2. A graduated series of products — The older generally most altered. L. 342, 346.)
   (1.) *Peat*, of the recent epoch — Mostly in northern temperate countries. (Réclus: *Earth*, 416-8.)
   (2.) *Brown Coal* or *Lignite* — Chiefly Cenozoic, in Germany, United States, etc. (See above I., 7, 8, 9.)
   (3.) *Bituminous Coal*:—Mesozoic and a portion of the Carboniferous. (D. 315; Marvine, *Hayden's Rep.*. 1873, 110; Hayden: *Ann. Rep.*, 1870, 179-88.) — Mineral Charcoal. (D. 316; Daws.: *Story*, 118; D. *Syst. Min.*, 755.
   (4.) *Cannel Coal*:—Chiefly Carboniferous. (D. 315.) — Also Green River Eocene; (Hayden: Ann. Rep., 1870, 144.) Produced by littoral attrition and redeposition. — Torbanite, Scotland. (D. 315, 316.)
   (5.) *Anthracite*:—Chiefly Carboniferous (D. 315.) — But in limited quantities in older and newer formations — Causes of anthracitization (L. 346.) — Highly altered Carboniferous in Rhode Island. (D 319.)
   (6.) *Plumbago*:—In Silurian and Archæan formations. (See above, I., 2.)
   (7.) Prof. Rogers' Classification of Coals. (*Geol. Penn.*, ii., 988-95; Fraser, *Hayden's Rep. Wyoming*, 1870, 180.)
   (8.) Nature of Coke. (D. 61.)

III. The Vegetable Origin of Coal (D. 351; Bischof; *Chemical Geology;* Websky in *Jour. f. Praktische Chemie*, xcii.; Hunt in *Am. Jour. Sc.*, II., xxxv., and *Canad. Nat.*, vi., 241; S. W. Johnson: *Peat and its Uses.*)

1. Chemical Composition. — Tables (D. 316, 361-2, 365: L. 343-5; D. *System. Min.*, 756-8: Rogers: *Geol. Penn.*, ii., 969-76; Marvine, Hayd. Rep., 1873, 110; Hayden: *Ann. Rep.*, 1870, 179-88; Peter, *Geol. Ky.*, 1856, 352-5, 361, 363, vol. iv., 243, 247-8, 266-9, especially 284-5; Whitney, *Geol. Cal.*, 30.) — Economical rank of Coals. (Rogers, *Geol. Penn.*, ii., 1000; Johnson, *Report to Congress.*)
2. Graduated series from wood to plumbago. (L. 343-5.)
3. Traces of vegetable structure.
   (1.) In the forms of fronds and fruits. (D. 317; Lesqx.: *Geol. Ill.*, iv., 479-89.)
   (2.) In vegetable tissue in coals themselves. (D. 318; Lesqx.; *Geol. Ill.*, iv., 478.)

4. Theories of conditions of coal-accumulation. (D. 360-4; L. 363.)
   (1.) A marine deposit. (Whittlesey, *Annals of Science.*)
   (2.) Formed of Drift-wood.
   (3.) Formed over sub-aërial surfaces.

IV. Stratigraphical associations of coal. (D. 311, 320; L. 335; Geol. Reports Ill., Io., O., Mo., Ky., Ind., Pa., etc.)

1. Shales. (D. 313.) — Character. — Fossil plants.
2. Clays. (D. 312.) — Stigmaria roots. (D. 313.) Fire clays and their properties.
3. Sandstone — Often gritty or conglomeritic. — Vegetable remains.
4. Limestones — Increasing westward. (D. 313.) — Marine animals.

V. Disturbances of Coal Fields.

1. Little disturbed in the Mississippi valley — Mich., Ind., Ill. — Highly bituminous — Little disturbed in the Rocky Mts. (Hayden, *Rep.* 1870, *Wyoming*, 180.
2. Greatly disturbed in the Appalchian region. (D. 396; L. 336.) — Pennsylvania. (D. 310; L. 337; Rogers: *Geol. Penn.*; Lesley: *Coal and its Topography* and *Geol. of Penn.*, New Survey.) — Debituminized. (Rogers: *Geol. Penn.*, ii., 808-11.) — Foreign regions. (D. 344-51.)

VI. Coal Fields of the United States. — 1. Appalachian. (Rogers: *Geol. Penn.*, ii.. 954-9.) — 2. Illinois. (Rogers: *ut sup.*, 959.) — 3. Rhode Island. — 4. Michigan. — 5. Eastern and Middle Rocky Mountains. (Frazer, *Hayden's Rep. Wyoming*, 1870, 179-86. See Lect. XIV.) — 6. Monte Diablo. (See above, I., 7.) — 7. Oregon. (See above, I., 8.) — 8. Alaska. (Dall: *Alaska and its Resources.*) — On the "Coal Fields of the United States and British Provinces," see Rogers: *Geol. Penn.*, ii., 942-54.

XII. COAL MEASURE TIMES.

1. Picture of a Coal-measure landscape. (W. 149-54.)

1. The thick dank forest. (D. 352, 353,; L. 369-70; Tyndall, *Proc. Roy. Soc.*, xi., 100 [*Am, Jour. Sci.*, II., xxxvi., 99]; T. S. Hunt: *Chemical and Geolog. Essays*, 42.) — Tree Ferns and dripping fronds. — A thick jungle. (D. 354.) — Prostrate trunks and decaying stumps. (D. 356.) — Land-snails, myriapods and insects. (D. 333-6, 339; L. 385; Daws.: *Story*, 112-5, 135-42; *Geol. Ill.*, iii., 556-72.)

2. A stagnant bayou. — *Archegosaurus.* (D. 351; L. 393; Daws.: *Story,* 145; Fig.: *World,* 139; Lyell: *Elem.,* 397.) — *Amphibamus* and its vocal utterances. (D. 340.) — *Eosaurus* inhabiting the waters. (D. 340, 343; L. 393; W. 170; Daws.: *Story,* 145-6.) — Dragon-flies depositing their eggs. (D. 335.) — Fishes. (D. 336, 343.)

3. A stormy beach and a sheltered lagoon. — Origin of cannel coal.

4. Views. (Dana, 322; W., 140, 142, 144, 146, 150; Daws.: *Story,* 126, 145; Fig.: *World,* 133, 138, 142; Lyell: *Elem.,* 393.)

II. A change of Scene. — Lowering skies. — Heaving sea-bottoms. — Invading waves. — Another submergence.

III. Results seen in modern coal-beds. W. 139-48.)

1. A stony herbarium. — Fairy tracery. — Delicacy and perfection of features.

2. What have we represented in this coal?

(1.) The very tissue and cell, and pith and root, and leaf and frond. (D. 317.)

(2.) The very carbon which poisoned the atmosphere æons ago.

(3.) The very sun-light which fell upon the forest, treasured up to be disengaged again in our winter fires. — Solar energy transformed and locked up, to be set loose in countless steam-engines of the human period. (Huxley, *Contemporary Review.*)

IV. Three Ends to be accomplished in Coal-making.

1. To purify the air for organic purposes. (D. 353; L. 373.) — The existence of *method* and *purpose* assumed.

(1.) The poison neither annihilated nor fixed in mineral combinations.

(2.) The agency of vegetation. (W. 160.)

(3.) The demand for respirable air coincident with the first epoch when the conditions of the land permitted the adequate development of the purifier.

2. To preserve the carbon for the coming man.

(1.) Tendency of vegetation to decomposition.

(2.) Organic substances preserved only in wet accumulations.

(3.) This need concurrent with the only epoch when the oscillations were sufficiently frequent.

3. To accomplish all things under the established method of world-building.

(1.) Oscillations of the level of the land. (D. 395.) — Foreshadowed in the False Coal measure and Conglomerate epochs. (D. 354.)

(2.) Special history of this period. (D. 354-60.) — Oscillations. (D. 357; W., 161.) — Alternate sea-bottom and verdant marsh. (D. 357-9; L. 366.) — Number of submergences. (D. 358.) — Warmth and dampness of the atmosphere. (See above, I.,1.)

(3.) The other ends demanded at the only time when the tension of the terrestrial crust could generate the requisite oscillations.

(4.) Grand closing events. (D. 395-401.) — Uplift of Appalachians. — Great enlargement of limits on the eastern wing of the continent. (L. 367; W. 161-2.) — Advent of the Middle Ages of the world's history. (L, 400.)

XIII. VEGETATION OF THE COAL MEASURES AND OLDER FORMATIONS.

D, especially 242, 255, 257-8, 268-71, 277, 279-80, 296-7, 321-31, 348-9; L. 346-63; W. 156-9.

DAWSON: *Story of the Earth and Man*, 121-32; *Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada*, Montreal, 1873.

FIGUIER: *The World Before the Deluge.*

LESQUEREUX: *Geology of Pennsylvania*, (1854), 1868, vol. ii., pt. ii., 835-84, Plates i-xx. — Synopsis in *New Amer. Cyclopædia;* Atlas to the Coal Flora of Penn., etc., 1879; Amer. Jour. Sci., Nov., 1860; *Geology of Ill.*, ii. 427-70, iv. 379-477; Pottsville Scientific Assoc., 1858, 1-23; *Fucoides in the Coal Formations*, Trans. Amer. Phil. Soc., 1866.

NEWBERRY: *Geology of Ohio*, i.,357-85; *Annals of Science*, Cleveland, 1853.

SCHIMPER: *Traité de Paléontologie végétale*, 1869.

H. C. WOOD, Jr.: *Flora of the Coal Period in the United States.* Trans. Amer. Phil. Soc., 1866.

On the Genesis and Migrations of Plants, see DAWSON, in *Princeton Review*, March, 1879, also the works there cited.

On plants older than the Carboniferous, see especially,

HALL: *Observations upon some spiral-growing Fucoidal remains in the Palæozoic Rocks of N. Y.*, xvi. Reg. Rep., 1863, 71-83; *Observations upon the genera Uphantænia, Dictyophyton, etc., op. cit.* 84-91; *The Flora of the Devonian period, op. cit.* 92-117.

DAWSON: *The Flora of the Devonian Period in Northeastern America*, Quar. Jour. Geol. Soc., xviii., 296; xvi. Reg. Rep. N. Y., 97-107; *Fossil Plants of the Devonian and Upper Silurian Formations of Canada*, Geology of Canada, 1871.

SYSTEMATIC ARRANGEMENT OF PALÆOZOIC VEGETATION.

[Extinct types in italics. Silurian, Devonian and Carboniferous types denoted respectively by S, D and C.]

PHÆNOGAMS.

ANGIOSPERMS.

Exogens. (Ordinary trees, shrubs and herbs.)

Endogens. (Palms, Sedges, Grasses, etc.)

GYMNOSPERMS.

Cycads.—*Cordaites* D. C, *Cardiocarpus* C; + *Pterophyllum* C.

Conifers D. C.—Araucariæ, Pines, Cypresses, Yews; *Prototaxites* S.D, *Pinites* C, or *Dadoxylon* (including *Sternbergia*), *Trigonocarpus* D. C, *Cardiocarpus* D. C, *Rhabdocarpus* C, *Araucaroxylon* D, *Whittleseya* C, *Annularia* C.

CRYPTOGAMS.

ACROGENS.

Equisetaceæ. (Horse-tails.)

Equisetids.

Calamitids D. C:—*Calamites* D. C, *Equisetites* C, *Annularia* C.

Asterophyllids D. C:—*Asterophyllites* C, *Sphenophyllum* C.

Filices D. C:—*Eopteris* S, *Caulopteris* D, *Neuropteris* D. C, *Cyclopteris* (*Nœggerathia* or *Palæopteris*) D. C, *Sphenopteris* D. C, *Callipteris* D. C, *Alethopteris* C, *Hymenophyllites* C, *Odontopteris* C, *Pecopteris* C, *Neriopteris* C, *Dictyopteris* C, *Alethopteris* C, *Staphylopteris* C.

Cyathaceæ—Tree Ferns,—*Caulopteris* D. C, *Psaronius* D, *Megaphytum* C.

Lycopodiaceæ—Club-mosses.

Lycopodids S. D.—*Psilophyton* S. D, *Arthrostigma* D.

Cyclostigmids:—*Cyclostigma* D, *Knorria* D. C.

Sigillarids D. C:—*Sigillaria* D. C,+ *Stigmaria* D. C, *Syringodendron* C, *Poacites, Cyperites, Sternbergia ?* C.

Lepidodendrids S. D. C:—*Sagenaria* S, *Lepidodendron* D. C, + *Lepidostrobus* C, *Halonia* C, *Selaginites* C, *Lycopodites* C, *Sahutzia* C, *Ulodendron* C, *Lepidophloios* C, *Lepidophyllum* C, *Sigillaria* + *Sigillarioides* (roots) + *Stigmaria* (floating stems) + *? Stigmarioides* (rhizomes) C. (See under *Sigillarids.*)

ANOGENS. (Mosses, Liverworts.)

THALLOGENS.

Lichens.

Fungi.

Algæ.

Confervæ.

Fucoides S. D. C.—*Palæophycus* S, *Buthotrephis* S, *Rusophycus* S, *Arthrophycus* S, *Spirophyton* D. C, *Caulerpites* C, *Chondrites* C, *Protophyta.*

Desmids (including Xanthidia.) (D. 257, 471; M. C. White, *Amer. Jour. Sci.*, xxxiii., 385-6.

Diatoms.

XIV. THE REIGN OF REPTILES, OR MESOZOIC TIME.

On American Mesozoic geology see, besides the references below, the Geological Reports of California, the Fortieth Parallel and of the Territories, under Dr. Hayden. Also MORTON: *The Cretaceous System of the United States.*

On the Vegetation of these Ages, see LESQUEREUX: *Cretaceous Flora of the Western Territories*, Hayden Survey, Vol. vi. 4to. 1874, and *The Tertiary Flora of the Western Territories*, Hayden Surv. Vol. viii. 4to. 1878. [These "Tertiary" plants are from the Lignitic or Laramie Group regarded by many as Cretaceous.] NEWBERRY: *Rep. on the Cretac. and Tertiary Plants*, in Hayden's Explor. Yellowstone and Missouri Rivers, 1859-60, 145-74. Also FONTAINE; *Notes on the Mesozoic Strata of Virginia*, Am. Jour. Sci. III. xvii. 25, 151, 229.

On the Reptiles and Mammals, see references under Lectures XV. and XVII.

I. The Mesozoic Continent.

1. Its Geography (D. 405, 422-3, 450-1, 455-8, 478-80, 481; L. 449, 451; W. 195-8). — Outlines (L. 451-2). — Forests (D. 451). — Emerging western limb. (See Lecture XXIII). — Topography.
2. Its Hydrography. (D. 420, 423; W. 195-8). — Drainage features. — Gulf of Mexico (D. 479). — Communication between the Caribbean and the Arctic Ocean. (D. 479). — Gulf of St. Lawrence. — Lake Superior and its outlet. — Niagara Falls in the olden time. — Hudson river and its outlet. (D. 422).
3. Views. (W. 177, 179, 181; Daws.: *Story*, 194, 219; Fig.: *World*, 172, 174, 206, 213, 222, 225, 229, 240, 258, 268).
4. European Mesozoic Geography. (D. 451, 480).

II. Triassic, Jurassic and Cretaceous Ages. (D. 403; L. 404).

1. Triassic subdivisions. — Trias in the U. S.
2. Jurassic subdivisions. — Occurrence in the trans-Mississippi.
3. Cretaceous subdivisions, European and American. (Lesqx.: *The Cretaceous Flora*, Hayden Surv. Vol. vi. 4to. 14; *Ann. Rep.* 1872, 371-427; *ib.* 1874, 316-65, 8 plates, monographic; Hayden, *Ann. Rep.* 1870, 87; Cope, in *Wheeler Rep.* Vol. iv. pt. ii. 1-13.) — Question of the age of the "Lignitic" or Laramie Group. (D. 457, 491, 493; L. 455-6; Newberry, *Am. Jour.*, II., xxix., 208-18; III., vii., 90; *Boston Jour. Nat. Hist.*, vii., 506: Lesquereux, *Am. Jour. Sci.*, II., xxvii., 359; *ib.* III., vii., 546; *ib. Hayden Ann. Rep.*, 1872, 417-42; *ib.* 1873, 365-425; *ib. The Tertiary Flora of the Western Territories*, Hayd. Surv., vii., 4to., 21-31, 309-355; *ib.* 1874, 275-315; Meek, *Hayd. Ann. Rep.*, 1862, 46-9; Hayden: *Ann. Rep.*, 1872 14; 1874, ch., i.-ii; Cope. *Bull. Hayd. Sur.*, i., 10; *ib.* Report *Vert. Pal, Col.*, Hayd., Ann Rep. 1873, 431-44; Marvine. *Haydn. Ann. Rep.* 1873, 106-28, 171-6; Stevenson, *Proc. Am. Phil. Soc.*, June, 1855;

Peale, *Hayd. Ann. Rep.*, 1874, 140-55, Comparison of opinions; Endlich. *Hayd. Ann, Rep.*, 1875, 195-207; King, *Geol.*, 40*th Par.*, i., 539; iii., ch., vii., on the western cordilleras; Comstock, in Jones *Rep. N. W. Wyom.*, 132-3.)

III. Marine Populations and Plants of Mesozoic Time.

1. Where their remains have been exhumed. (D. 405-7,431.) — Atlantic and Gulf-border. (D. 455; L. 439.) — Marl-beds of New Jersey. (D. 455; Daws.: *Story*, 329.) — Prairie Bluff and Choctaw Bluff, Ala. (W., *Proc. Am. Assoc.*, 1858 and 1856.) — Western Territories. (D. 456-7; L. 440.) — Pacific border. (D. 457 L. 440.)

2. Palæozoic Types extinct:—

(1.) Plants:—Lepido dendrids, Sigillarids Cyclostigmids, Calamites.

(2.) Radiates:—Graptolites. (D. 384.) — Cystids. (D. 385.) — Blastids. — Favositsoid and other corals.

(3.) Brachiopods:—Orthids, Productids.

(4.) Cephalopods:—*Goniatites* (in Triassic), *Clymenia, Gomphoceras, Endoceras.*

(5.) Articulates:—Trilobites, Eurypterids.

(6.) Vertebrates:—Heterocercal Ganoids. (D. 384, 441.).

2. Palæozoic Types greatly shrunken:—

(1.) Plants:—

(2.) Radiates:—Cyathophylloids, Crinoids.

(3.) Brachiopods. (Daws.: *Story* 221.)—*Spirifer, Leptæna*, Brachiopods generally.

(5.) Vertebrates:—Placoderm Fishes.

4. New Types introduced or greatly developed.

(1.) Plants:—Cycads. (D. 408; L. 416-7.) — Angiosperms. (D. 459; L. 457.) — Palms.

(2.) Protozoans:—Rhizopods. (D. 460; L. 459.)

(3.) Radiates:—Astræoid corals, Echinoderms. (L. 460.) — Asterioids. (L. 419-20.)

(4.) Molluscs:—Lamellibranchs. (L. 461.) — Ammonites. (D. 439; 462-3, 467; L. 421, 464; Daws.: *Story* 221.) — Belemnites. (D. 440, 432-4.) — Structure and affinities of Ammonites. (D. 409-10; L. 422; L. Ag.: *Geol. Sk.*, 177-9, Lect., VII., III., 3.) — Geological history of Cephalopods. (L. 425.)

(5.) Articulates:—Macrouran Crustaceans. (D. 441.)

(6.) Vertebrates:—Teleost Fishes. (D. 442, 462, 475; L. 466.) — Zoölogical characters. (Huxley; *Vert.*, 130-44.)

IV. The Air-breathing denizens of the land and waters.

1. Classification of Amphibians and Reptiles.

2. Conspicuous Mesozoic types:—Ichthyopterygians. — Pythonomorphs (Mosasaurs.) — Crocodilians. — Sauropterygians. — Dinosaurs. — Ornithosaurs. — Turtles. (D. 466; W. 190.) — Geological succession among reptiles. (Cope., *Proc. Am. Acad. Boston*, xix., 194; *Am. J. S.*, ii., 217.)

3. Scenes on the banks of the future Delaware.

4. Scenes in the future valley of the Connecticut. — Bipedal Reptiles. (D. 412; L. 431, 443-4; W. 168, 183-7; Ag.: *Sketches*, 150-4.)
5. Advent of Birds. (D. 414, 466, 468; L. 470, 472; Daws. *Story*, 208; Marsh, *Am. Jour., Sci.*, March 1860; 1872, 56, 360, March, 1873: Allen, *Bull. Hayd. Surv.* iv., 443, Apr., 1878.) — Birds with vertebrated tails. (D. 414, 430, 446-7, 468; L. 436-7, 420; W. 184; Fig.: *World*, 229; Mivart: *Genesis of Species.*) — Birds with biconcave vertebræ and sharp teeth. (D. 466; L. 470; Marsh, *Am. Jour.*, May 1872, 344; Jan., 1873, 74; Feb., 1873; x., Nov., 1875, plates; xi., June, 1876. 509; xiv., July 1877, 85, plate; xvii. 266.)
6. Advent of Mammals. (D. 415, 427, 429, 446, 449-50; L. 438; W. 188; Daws.: *Story*, 208. Lecture, XVII., II., i., and III., i.) — Their Marsupial affinities. (D. 415, 430; L. 438; Daws.: *Story*, 209.) — Unknown through the Cretaceous. (D. 466; L. 372.)

V. Disturbances. (D. 417. Lecture XX., V.)

1. Trias and eruptions of Trap. (D. 417-20, 421.)
2. Jurassic closed by uplift of mountains. (D. 452-3; L. 450. — Sierra Nevada and Basin ranges to the east. (D. 452, 486; Whitney: *Geol. Cal.*; King: *Rep.* 40*th. Par.*, i., 734-54, 759. — Humboldt range. (D. 453, 486.)
3. Cretaceous closed by uplifts:—Wahsatch Range. (King: *Rep.* 40*th. Par.*, 745, 747, 753, not D. 453, 486.) — Uinta Range. (King: *op. cit.*, 540, not D. 453, 486. Lecture XXV., I., 7.) California west of Sierra Nevada. (D. 523.) — Part of Rocky Mts, east of Wahsatch. (Lect, XXV., I., 7.) — Increased cold and extermination of species. (D. 487; L. 475; Daws.: *Story*, 232.)

XV. SOME EXTINCT TYPES OF REPTILES.

For a completer list of extinct American Reptiles, see Supplement, "Aids to Advanced Study."

IMPORTANT REFERENCES:

E. D. Cope:—I. *Synopsis of Extinct Batrachia, Reptilia and Aves of North America.* Trans. Amer. Phil. Soc., 1869 and 1870.

II. *Vertebrata of the Cretaceous Formations of the West.* Hayden Survey, ii., 4to., 1874. For *literature* to date, see pages 51-3. For synopsis of known Cretaceous Vertebrata of N. Amer., see pp., 245-302.

III. *Report on the Vertebrate Palæontology of Colorado.* Hayden Ann. Rep., 1873, 427-533.

IV. *Descriptions of some Vertebrate Remains from the Fort Union Beds of Montana.* Proc. Acad. Nat., Sci. Phil., 31 Oct., 1876.

V. *On some Extinct Reptiles and Batrachians from the Judith River and Fox Hills beds of Montana.* Proc. Acad. Nat. Sci., Dec., 1876.

VI. *Batrachia of the Coal Measures of Ohio.* Proc. Amer. Phil. Soc., Feb., 1877.

VII. *Geology of the Judith River beds, Montana, and the Niobrara Cretaceous.* Hayden Bulletin, iii., No. 3.

VIII. Palæontological Bulletin, No. 28. Proc. Amer. Phil. Soc., 21 Dec., 1877.

IX. *Extinct Batrachia and Reptilia from the Permian Formation of Texas.* Proc. Am. Phil. Soc., 5 Apr., 1878.

X. *Report upon the Extinct Vertebrata obtained in New Mexico by parties of the Expedition of* 1874. Wheeler Survey, vol., iv., pt., ii.

JOSEPH LEIDY :—I. *Cretaceous Reptiles of the United States.* Smithsonian Contributions to Knowledge, 1863.

O. C. MARSH, in American Journal of Science and Arts, IIId. Series. The references denote volume and page.

Leidy and Cope are cited by the Roman numerals prefixed to their papers. The references to "Hux." signify: *A Manual of the Anatomy of Vertebrated Animals*, Am. ed., 1872.

I. Classification of Amphibians and Reptiles. (Hux., 149, 169. Compare Cope, *Bull. U. S. National Museum*, No. 1, and C. I., 4-6, 26-9.)

1. Tabular analysis of Orders of the two Classes.
2. Amphibia differentiated from Fishes. (Hux., 149.) — From Reptiles.
3. Reptiles differentiated from Amphibia. (Hux., 167-9.) — From Birds. (Hux., *Proc. Zoöl. Soc. Lond.*, Apr., 1867.)

II. Amphibians.

1. Urodela (Stegocephali, C. I., 6.)
   (1.) Salamandrids :—*Ichthycanthus.* (C. VI., 573.) — *Leptophractus.* (C. VI., 576.)
   (2.) Xenorhachia (Cope, *Geol. Ill.*, ii., 137) :—*Amphibamus.* (Cope, *P. A. N. S.* 1865, 134; *Geol. Ill.*, ii., 135-41.) — *Tuditanus.* C. VI., 577.)
   (3.) Microsauria. (Dawson,) :—*Pelion=Raniceps.* (Wyman, *Am. Jour. Sci.*, 1858, 158; W. 170; C., I., 9.) — *Hylonomus.* (Daws. : *Story*, 146, 148; *Can. Nat.*, viii, 167.) — *Sauropus.* (D. 302; Lea, *Trans. A. P. Soc.*, x. 1852.) — *Dendrerpeton.* (Daws. : *Story*, 146; Owen, *J. Geol. Soc.*, 1853, 81; C. I. 12.)
   (4.) Ganocephala :—*Colosteus.* (C., I., 22.) — *Rhachitomus.* (C., ix., 526.)
2. Labyrinthodonta. (Hux., 154-5; Fig. : *World*, 170.) — Characters and geological history. (L. 409; W. 172-4, 176-7.) — Footprints. (D. 412; Hitchcock : *Ichnology of New England*; L. 409.) — *Dictyocephalus.* (Leidy, *P. A. N. S.*, 1856, 256.) — *Baphetes.* (Daws. : *Story*, 145-6; Owen, *Q. J. Geol. Soc.*, 1853.)

III. Plesiosaurs. — Structure and affinities. (Hux., 180-6.) — *Plesiosaurus.* (D. 443; L. 430; W. 178-9; Ag.: *Sketches*, 160; Daws.: *Story*, 213; Fig.; 201-6.) — *Pliosaurus.* (L. 430.) — *Polycotylus.* (D. 467; C., *P. A. N.* S., 18 June, 1869; I., 34-8; II., 70-5.)

IV. Lacertilians. — Characters. (Hux., 186-93.)

1. Rhynchocephals. (Hux., 194; Marsh, xv., 409.) — *Nothodon.* (Mh., xv., 410.) — *Cricotus.* (C., P. A. N. S., 1875, 405.) — *Clepsydrops.* (C., *P. A. N. S.*, 1875, 407.)
2. Homœosaurs. (Hux., 195-6):—Triassic *Telerpeton.* (D. 427, 428; W. 166; Hux., *Q., J. Geol. Soc.*, xxii.)
3. Protorosaurs. (Hux., 195-6.) — Permian *Protorosaurus.* — *Crematosaurus.* (C., III., 515.)
4. Monitors or Platynota. Hux., 193, 196):—*Saniva.* (Leidy. P. A. N. S., 1870, 124.) — *Thinosaurus.* (Mh., iv., 229, Oct. 1872.) — *Glyptosaurus.* (Mh., i.. 456, June, 1871; iv., 302, 305.)

V. Pythonomorphs or Mosasaurs. (C., I., 182; Owen, *Q. J. G. S.*, 1879, 682; C., *Hayden Surv. Bull.* iv., No. 1; Mh. iii., June, 1872. See synopsis, C., II., 264-72.) — *Mosasaurus.* (D. 464, 465, 468, 474; L. 469; Daws.: *Story*, 216-7; especially Fig.; *World*, 264-8; Leidy, I., 30-74. See further, *Supplement*) — *Discosaurus-Elasmosaurus*, Cope. (D. 464, 467; L. 467; Leidy, I., 22-5; W. 190; Daws.: *Story*, 217-8. See Suppl. [*D. carinatus* of Kansas had 72 cervical vertebræ; *Plesiosaurus* had 24-41.] — *Edestosaurus.* (D. 468; Mh., i., 447.) — *Cimoliasaurus.* (W. 190; C., I., 40-4; Leidy, I., 25-9.)

VI. Ichthyosaurs. (Hux., 208-14):—*Ichthyosaurus.* (D. 442-3; L. 429; W. 138-9; Ag.: *Sk.* 158-9; Daws.: *Story*, 213; Fig.: *World*, 194-200; C. I. 29.) — Resemblance to Cetaceans. (Hux., 208; D. 443; W. 178-9.) — A composite type. (Ag.: *Sk.* 159.) — *Eosaurus.* (Mh. II., xxxiv., July, 1862; W. 170.)

VII. Crocodilians. — Characters. (Hux., 214-21.) — Tabular analysis of Families.

1. Alligatoridæ:—*Alligator.* (C. *Hayd. Ann. Rep.*, 1872, 614; C. V. 15.)
2. Crocodilidæ:—*Crocodilus.* (C. *Hayd. Ann. Rep.*, 1872, 612; C. VI. 31-4; C. X, 62; Mh. i., 553.) — *Diplocynodus.* (C. *Hayd. Ann. Rep.*, 1872, 613; VI. 31, X, 60.)
3. Gavialidæ:—*Thoracosaurus.* (D. 467; Leidy, I, 5-12.)
4. Teleosauridæ:—*Teleosaurus.* (L. 431; Fig.: *World*, 225.) — *Hyposaurus.* (D. 467; Leidy, I., 18; C. I., 23; C. II., 67-80.)
5. Belodontidæ:—Belodon, perhaps a Lacertilian. (D. 428; C. I., 56-61.)

VIII Dicynodonts and Theriodonts. — Characters and history of Dicynodonts. (L. 410.) — Combined characters of crocodiles, tortoises and lizards. (Owen, .) — Characters and history of Theriodonts. (L. 411; Owen, .)

IX. Ornithoscelids. (Hux., 223-32; L. 431.) — Characters intermediate between Reptiles and Birds. (Hux., 224-6; L. 431.) — Structure of pelvis. — Position of Pubis and Postpubis. (Mh. xvi., 417, plate: xvii., 90.) — The hind-limbs. — Many bipedal. (Mh. xvii., 91.

1. Dinosaurs. (D. 413, 464; L. 431, 452; C. I., 86-90; Mh. xvi., 412.)

(1.) Permian:—*Lysrophus.* (C., P. A. N. S., 1877, 187.) — *Bolosaurus.* (C. IX., 506-8.)

(2.) Triassic:—*Thecodontosaurus.* (C. VIII., 231.) — *Palæosaurus.* (C. VIII., 232.) — *Clepsysaurus.* (D. 413; Lea, *Jour. A. N. S. Phil.*, ii., 4to. pt. 3, 1852.) — *Bathygnathus.* (D. 414; L. 447; W. 178, 184; Leidy, *Jour. A. N. S.*, 1854, 327; C. I., 119.) — *Megadactylus.* (C., I., 122 A.)

(3.) Jurassic:—*Megalosaurus.* (D. 444; L. 433; Fig.; 255.) — *Celeosaurus.* (L. 434; Daws.: *Story*, 204.) — *Pelorosaurus.* (W. 188; Mantell, *Phil. Trans.*, 1850, pt. 2, p. 379.) — *Iguanodon.* (L. 431; W. 189; Fig.: *World*, 258; D. 445: Mantell: *Foss. of Brit. Mus.*, 224-313; *Isle of Wight*, 227-34.) — *Amphicœlias.* (C. *Pal. Bull.* 27; C. VIII., 233, 242-6. [C. says cretaceous, kangaroo-like, and *A fragillissimus* over 100 ft. in length. (C. in *San Francisco Acad. Sci.*, 1879.)]

Suborder SAUROPDA. (Atlantosauridæ, Mh. xvi., 412, Nov.. 1878)—*Atlantosaurus*=*Titanosaurus*, Mh. (Mh. xiv., 87, 514; xv., 241; xvi., 412; xvii., 88; L. 468). Mh. estimates it 80 ft., in length, and says it was the largest land animal so far known.

Suborder SAURANODONTA. (Mh. xvii., 85): — *Sauranodon.* (Mh. xvii., 86.) — *Camarasaurus*=? *Chrondrosteosaurus*, Owen, *Ann. and Mag. Nat Hist.*, ii., 101, Sep., 1878, (C., P. A. N. S., 20 July, 1877, 7; C., VIII., 233-42; Mh, xvii. 89.) C. says it is Cretaceous, and *C. supremus* was 72 ft in length.

Family Allosauridæ, having affinities with Megalosauridæ. (Mh. xviii., 89): *Allosaurus.* (Mh. xiv., 515.) — *Creosaurus.* (Mh. xv., 243; xvii., 90.)

Family Nanosauridæ, having affinities with *Compsognathus.* (Mh. xv., 224; xvii., 90.) — *Nanosaurus.* (Mh. .)

(4.) Cretaceous:—*Hadrosaurus.* (.D 464, 467; L. 467 468; W. 192-3; Daws.: *Story* 202; Leidy, *Cretac. Reptiles*, U. S., 1865, 76-97; C. I., 91-8, 122L-122 J. See references, C. II., 247.) — *Lælaps*=*Dryptosaurus*, Koch, (D. 464; W. 191; Daws.: *Story*, 203; C., P. A. N. S. June, 1866; I. 100-18; IV., 1-2; V., 1-5; Hayd. Bull. iii., 4, 805.) — *Ornithotarsus.* (D. 464: L. 468; C., P. A. N. S., 18 June, 1869; I. 120-1.) —

2. Compsognaths. (Hux., 225, 228; L. 434 — *Compsognathus.* (L. 434.)

X. Pterosaurs. (D. 464; Daws.: *Story*, 265-7; Hux., 228-32.) — General characters. — Doubtful *Ornithopterus.*

1. With fully toothed jaws — *Pterodactylus.* (D. 446, 468; W. 178, 180-1; Mh. xv. 233, Sep., 1878; xvi. 411, Nov., 1878.)
2. With jaws produced into toothless beaks. — *Rhamphorhynchus.* (D. 446, misnamed—after Goldfuss. — *Pterodactylus;* (L. 435; W. 183-4; Ag.; *Sk.* 162.)

3. With jaws entirely toothless. — *Pteranodon.* (L. 468; Mh. iii., Apr., 1872; xi. 507, June, 1876; Cope I., 169-75; II. 65.)

XI. Chelonians. — *Testudo.* (Leidy, I, 101-111; *Extinct Vert. Fonna West. Terr.*, Hayd. Surv., 339-40; C. X, 283.) — *Compsemys.* (Leidy, *Trans. A. P. S.*, 1860, 152; C. II., 91; IV. 10. — *Adocus.* (C. I., 232-3; II. 91.)

XII. Ophidians:—*Palæophis.* (C. *Geol. N. J.*, 1868, 737; P. A. N. S., 1868, 147, 234; *Trans. A. P. Soc.*, 1869, pl. xiv.) — *Dinophis.* (Mh. II., xlviii., 397.) — *Boavus.* (Mh. i., 322-4.)

XVI. THE REIGN OF MAMMALS, OR THE TERTIARY AGE.

See especially, the official geological reports of New Jersey, South Carolina, Alabama, Mississippi, Tennessee, California, British Columbia, and those conducted by Hayden, King and Wheeler. Also, Conrad: *Tertiary Fossils of the United States;* Tuomey and Holmes: *Fossils of South Carolina,* 4to., 1855.

I. The Continent during the Tertiary Age.

1. Its approximate completeness. (D. 521-2.) — Outlines. (L. 479-80; W. 200.)
2. Intracontinental seas. (D. 491; L. 479, 512; W. 200-1. See Lect. XXIII.) — Relics of the Mesozoic intercontinental channel. (L. 511-2; W. 199.)
3. Arboreal vegetation and its modern aspects. (D. 497-8; L. 481-3; Lesquereux: *Tertiary Flora,* Hayden Rep., 4to. vii.; but see Lect. XIV.)
4. Stratification. (King, *Geol. 40th Par.* ch. v.; Lesqx. *Tert. Flor.* Hayd. Surv. vii., 10-20, 24; *Hayden Ann. Rep.* 1870, 93; 1874, 23; Marsh, xvi., Plate, iv.; *Proc. Am. Assoc. Adv. Sci.* 1877, 210.)
5. Views. (Daws.: *Story,* 253; Fig.: *World,* 288, 309, 329. Also, especially, the Reports of Hayden, King, Wheeler and Powell.)

II. Marine Animals. — Approximation to modern types. (D. 499-501; L. 486-7.) — Subdivisions based on percentages of living species. (D. 489; L. 476-7; Daws.: *Story,* 239.) — *Zeuglodon.* (D. 502; L. 500-1; W. 203; Leidy: *Extinct Mam. Dakota,* 427; *Extinct Vert. Fanna Ter.*, 1873, 337.) — *Squalodon.* (Leidy, *Extinct Mam. Dak.*, 416-24.) — Comparison of *Zeuglodon* with the Mosasaurs. — Other marine mammals.

III. Decadence of the Reptilian Dynasty.

1. Total extinctions. (L. 492): — Dinosaurs, Pterosaurs, Ichthyosaurs, Plesiosaurs, Dicynodonts.
2. Types shrunken:—Lacertilians, Crocodilians.

3. Types conserved and developed :—Chelonians. (*Colossochelys*, D. 516, 520 ; L. 493.) — Ophidians. (D. 509, 576.)

IV. Rise of Mammalian Rule.

1. Sudden abundance at the beginning of this age. (L. 495.)
2. Their predominantly placental character. (L. 495.)
3. Already considerably differentiated. (L. 495 ; Daws. : *Story*, 244.) — Types. (Mh., *Proc. Am. Assoc. Adv. Sci.*, 1877, 211-58) :— Zeuglodont, Sthenorhine (both tapiroid and horned), Equine, Carnivorous, Insectivorous, Rodent, Cheiropterous, Quadrumanous. — Many of these Marsupial.
4. But these types not completely differentiated. — All the types comprehensive. (L. 508, 509-10.) — Became progressively more differentiated. — Hence supposed to have proceeded from types still more comprehensive. (L. 511.) — The Pantodont type. (L. 506-7 ; Cope, *P. A. N. S.*, Feb., 1873 ; *On the Extinct Vertebrata of the Eocene of Wyoming*, Hayd. Ann. Rep. 1872, 585-9 ; *Palæont. Bullet.*, No. 28, Proc. A. P. Soc. 21 Dec., 1877, 24-30, order AMBLYPODA proposed.)

V. The Cemeteries of the Animals. (W. 204-5.)

1. Why their remains are not generally distributed.
2. The areas called "Bad Lands." (D. 492, 494, 495 ; L. 478-9 ; W. 205-10. See also Lect. XXVII., II., 4, (4) f.) — A picture of desolation. — An ancient sea freshening to a lake. — The lake gradually filled with sediment. (D. 491.) — Life upon its borders. — Inhumation of skeletons. — Erosions of later times.
3. Sequence of Tertiaries and names of Lakes. (King, 40th Par. i., 458 ; Mh. *A. J. S.*, III., ix., 49 ; Grinnell and Dana, *ib.*, xi., 126.) — Three geographically distinct Tertiary Basins ; probably more.

(1.) Eocene (in the middle province).

(*a.*) Vermillion Creek Group, King—Wahsatch Gr., Hayden. — Deposited in UTE LAKE. — Between Wahsatch and Rocky Mts., from Wind R. Range south to New Mexico. — The Uinta Range an island. — *Coryphodon*, *Eohippus*, *Oxyæna*, *Meniscotherium*, etc. (King, i., 376-7.)

(*b.*) Green River Group, Hayden—Elko Gr., King. — Deposited in GOSIUTE LAKE. — Nearly the same as last, with doubled east and west dimensions. — Wahsatch and adjoining highland a peninsula ; Uinta still an island. — Fishes, Insects.

(*c.*) Bridger Group. — Deposited in WASHAKIE LAKE. — Wholly within the boundaries of Ute Lake. — *Dinoceras*, *Tinoceras*, *Uintatherium*, *Orohippus*, *Palæosyops*, etc.

(*d.*) Uinta Group. — Deposited in UINTA LAKE, south of Uinta Mts., in valley of Green and White rivers. — *Hyopsodus*, *Epihippus*, *Agriochærus*, etc.

(2.) Miocene. — Two contemporaneous basins.

Truckee Group, King—John Day Gr., Marsh. — Deposited in PAH UTE LAKE, (Province of Nevada and Oregon.) — East of Cascade and Sierra Nevada Ranges, from Columbia river south into California. — *Rhinoceros Pacificus, Eporeodon, Diceratherium, Miohippus*, etc.

White River Group, Hayden. — Deposited in SIOUX LAKE, (Province of the Great Plains). — From Northern Kansas far into British Columbia, and west nearly to Colorado Range. — *Menodus, Brontotherium, Oreodon, Mesohippus, Poebrotherium. Dinictis*, etc.

(3.) Pliocene. — Three contemporaneous basins.

Humboldt Group, King. — Deposited in SHOSHONE LAKE, (Province of the Great Basin). — Covering Pah-Ute Lake and stretching east over the Great Basin to Wahsatch Mts. — *Protohippus, Merychippus, Dicrocerus.*

North Park Group, Hague and Hayden. — Deposited in NORTH PARK LAKE, (Middle Province). — North Park and upper valley of North Platte River. — No fossils.

Niobrara Group, Marsh. — Deposited in CHEYENNE LAKE, (Province of the Great Plains). — Superimposed on, and overlapping Sioux Lake on all sides; stretching southward to the Gulf and northward into British Columbia. — *Protohippus, Pliohippus, Procamelus, Dicrocerus*, etc.

4. Atlantic and Gulf-border Tertiaries. (D. 491, 494, 495; L. 477.)
5. Foreign Tertiary Basins. (D. 512; L. 480.) — The Paris Basin. (D. 512, 513; L. 496-8.) — What Cuvier dug from it. (D. 513, 517-8; W. 202; Daws.: *Story*, 240; Agassiz: *Sketches*, 185-90.) — Reminiscence of Montmartre and the Buttes Chaumont. — The Vienna Basin. (D. 515.) — The London Basin. (D. 511, 513; Daws.: *Story*, 245, 247.) — Himalayan deposits. — The monarch of proboscideans. — *Sivatherium.* (D. 520; L. 498-9.) — *Colossochelys.* (D. 516, 520; L. 493.)

VI. A Glimmering from the Future.

VII. Disturbances of the Tertiary Age. (L. 512; Daws.: *Story*, 236-7. See Lect. XXV.) — Some cordilleras in Wyoming, Utah and California. — Coast Range, Cal. (D. 523; L. 256.) — Enormous outflow of lava along the Pacific slope. (L. 512; See also Lects. II. and XXVI.) — Pyrenees, Appenines, Carpathians, Alps.

VIII. Parallelism of European and American Formations. (Cope, *Hayden Bulletin*, v. No. 1, 33-54; Marsh, xvi., pl. iv., Nov. 1878.)

XVII. SOME EXTINCT TYPES OF MAMMALS.

[For a completer list of Extinct American Mammals, see "Supplement."]

GENERAL REFERENCES.

LEIDY:—I. *The Ancient Fauna of Nebraska.* Smithsonian Contributions to Knowledge, 1853.

II. *Extinct Mammalia of Dakota and Nebraska*, in Jour. Acad. Nat. Sci. Phil., vol. vii., 1869.

III. *Extinct Vertebrate Fauna of the Western Territories.* Hayden Survey, 1873, vol. i., 4to.

COPE:—I. *Synopsis of the Extinct Mammalia of the Cave Formations of the United States*, Proc. Amer. Phil. Soc., July, 1869.

II. *Preliminary Report on the Vertebrata discovered in the Port Kennedy Bone Cave*, Proc. Am. Phil. Soc., Apr. 7, 1871.

III. *On the Extinct Vertebrata of the Eocene of Wyoming*, Hayden Ann. Rep., 1872.

IV. *Report on the Vertebrate Palæontology of Colorado*, Hayden Ann. Rep., 1873, 427-533.

V. *Report on the Stratigraphy and Pliocene Vertebrate Palæontology of Northern Colorado*, Bulletin, Hayden Survey, No. 1.

VI. *Descriptions of New Vertebrata from the Upper Tertiary Formations of the West*, (Palæontological Bulletin, No. 28), Proc. Am. Phil. Soc., 21 Dec., 1877.

VII. *Descriptions of new Extinct Vertebrata from the Upper Tertiary and Dakota Formations*, Hayden Survey, Bulletin, vol. iv., No. 2, May 3, 1878.

VIII. *Report upon the Extinct Vertebrata obtained in New Mexico by parties of the Expedition of* 1874, Wheeler Survey, vol. iv., pt. ii., 4to.

IX. *On some of the Characters of the Miocene Fauna of Oregon*, Proc. Amer. Phil. Soc., 15 Nov., 1878.

X. *Observations on the Faunæ of the Miocene Tertiaries of Oregon*, Hayden Surv. Bul., v. No. 1, 55-67.

XI. *On the Extinct Species of Rhinoceridæ of North America and their Allies*, Bul. Hayd. Survey, v. No. 2, 227-37.

[The general works cited above supersede many of Leidy's and Cope's numerous preliminary contributions, and hence such contributions are not quoted.]

MARSH:—Numerous papers in *American Journal of Science and Arts*, series III. These are cited by volume and page.

Leidy and Cope are cited by the Roman numerals prefixed to their publications, as above.

I. Classification of Mammals. (HUX., *Anat. Verteb. Anim.*, 273; Gill, *Smithsonian Misc. Coll.*, Nov. 1872, 8vo., 98pp.

1. Tabular analysis of the Orders.
2. The types becoming progressively differentiated through time.

II. Triassic Mammals.

1. American:—*Dromatherium sylvestre.* (D. 415, 417; Emmons: *Geol. N. C.*) — An insectivorous Marsupial. (D. 416-7.)
2. Foreign:—*Microlestes antiquus.* (D. 429.) — Related to above.

III. Jurassic Mammals.

1. American:—*Dryolestes priscus.* (Mh. xv., 459; xvi., 411.) — *D. vorax.* (Mh. xviii., 215, Sep., 1879.) — *Stylacodon gracilis.* (Mh. xviii., 60.) — *Tinodon bellus.* (Mh. xviii., 215, fig., Sep., 1879.) — All insectivorous Marsupials.
2. Foreign:—(1.) Great Oölite of Lower Oölite:—*Amphitherium, Thylacotherium.* (D. 448, 449; Fig.: *World*, 216.) — *Phascolotherium.* (D. 448, 449; Fig.: *World*, 216, 223.) — *Stereognathus.* (D. 447.)

   (2.) Purbeck beds of Upper Oölite:—*Plagiaulax.* (D. 450.) — *Spalacotherium.* — *Galastes.* (D. 448.) — *Stylodon.* (Owen, *Geol. Mag.*, iii., 199; *Palæont. Soc.*, xxiv., 45.)
3. All Marsupials. — *Plagiaulax* were rodent, *Galastes* carnivorous, and all the others, insectivorous. — Seventeen European Jurassic species in all.

IV. Eocene Terrestrial Mammals.

1. American [Alabama Period. (D. 508-11.) — Green River and Vermillion Creek Groups. (King, *Geol.* 40*th Par.*, i., 355) + Bridger and Uinta groups.]

   (1.) MARSUPIALS:—*Triacodon.* (Mh. ii., 123; iv., 222-3; C. III., 611.)

   (2.) AMBLYPODA:—(C. VIII., 179, 282.)

   Suborder PANTODONTA. (C. III., 187):—*Coryphodon.* (L. 502, 506-7; Mh. xi., 425, May, 1876, pl.; C. VIII., 187-250; *P. A. N. S.*, 1877, 616, brain; Owen, *Brit. Foss. Mam. and Birds*, 299.) — *Bathmodon.* (C. III., 585-8; V., 8 10; VI., 24-8; VIII., 187-250)

   Suborder DINOCERATA, Cope. [See below.]

   (3.) DINOCERATA. (Mh. v., Feb., 1873, plates; Apr., 1873, and Sup. Note; *P. A. N. S.*, 8 Apr., 1873; vii., App. June, 1873; xi., Feb., 1876, plates; C. III., 563-85; Owen, *Amer. Jour.*, xi., 401, questioning the presence of horns):—*Uintatherium.* (D. 504: Leidy, III., 93-103, 331-4; C. III., 580. — *Dinoceras.* (D. 504; L. 503, 506-7; Mh. iv., 343; v., 117, 293, 310; xi., 163, plates.) — *Tinoceras.* (Mh. iv., 322, 343; v., 293; *Am. Nat.* Jan., 1873, 52.) — *Eobasileus.* (C., *P.A.N.S.*, Jan. and Feb., 1873; C. *Am. Nat.*, vii., 1, May, 1867; C. III., 564, 575-80; C. IV., 456.) — These, with *Loxolophodon*, Cope, are thought by Leidy to represent only one genus. (L. III., 332.)

   (4.) PERISSODACTYLA. (Hux., 292):—(*a.*) Coryphodontidæ. (Mh. xi., 428; xiv., 81, plate:—[See above.] — (*b.*) Equidæ. (Hux., 295; Mh. vii., 255; viii., 288; L. 509-10):—*Eohippus.* (Mh. xii., 401.) — *Orohippus.* (Mh. iv., 207; v., 407; vi., 19-22; vii., 247; ix., 247; C. vi., 19-21.) — (*c.*) Tapiridæ. (Hux., 310; Compare Cope on *Rhinocerida and related Perissodactyls*, C. IX., 228.) — *Lophiodon.* (Leidy, II., 391; III, 219, 327; Mh. ii., 36.) — *Palæosyops.* (L. 504; Leidy, III., 323-6); C. III., 591; Mh. ii., 36-8.)

   (5.) ARTIODACTYLA. (Hux., 312):—Suidæ:—*Homacodon.* (Mh. iv., 126.)

   (6.) BUNOTHERIA. (C. VIII., 72.):—

   Suborder CREODONTA. (C. VIII., 85):—*Ambloclonus.* (C. VIII., 90-4.) — *Oxyæna.* (C. VIII., 95-105.) — *Didymictis.* (C. VIII., 123-6.)

   Suborder MESODONTA. (C. VIII., 85:—*Microsyops.* (Leidy, III., 82, 320.) — *Tomitherium.* (C. III., 546-8; VIII., 135-45.) — *Antiacodon.* (Mh. iv., 210.)

Suborder INSECTIVORA. (C. VIII., 85):—*Talpavus.* (Mh. iv., 128.) — *Anisacodon,* (Mh. iv., 209.) — *Esthonyx.* (C. VIII., 153.)

Suborder TILLODONTA. (C. VIII., 85):—[See below.]

Suborder TÆNIODONTA. (C. VIII., 85, 157):—*Ectoganus.* (C. VIII., 158-62.) — *Calamodon.* (C. VIII., 162-70; C. *P. A. N. S.*, March, 1876.)

(7.) TILLODONTIA. (Mh. xi., 249-51, plates):—*Tillotherium.* (L. 504; Mh. v. 485; ix., 241: xi., 249, plates; C. VIII., 84, 85.) — *Anchippodus.* (Leidy, II., 403; III., 328; Mh. ix., 241.)

(8.) RODENTIA:—*Plesiarctomys.* (C. VIII., 170-2.) — *Sciuravus.* (Mh. ii., 122; iv., 220.)

(9.) CARNIVORA:—*Limnocyon.* (Mh. iv., 126, 203.) — *Limnofelis.* (Mh. iv., 202). — *Canis.* (Mh. ii., 123.) — *Synoplotherium.* (C. III., 554-9, plates; VIII., 75, 77.)

(10.) CHEIROPTERA:—Nyctitherium. (Mh. iv., 127; v. 405.) — *Nyctilestes.* (Mh. iv. 215.)

(11.) PRIMATES:—(*a.*) Lemuravidæ. (Mh. ix., 289; xii., July, 1876):—*Lemuravus.* (Mh. ix., 239.) — (*b.*) Limnotheridæ. (Mh. ix., 239):—*Thinolestes.* (Mh. iv., 205.)

2. Foreign. (D. 516-20.)

(1.) PERISSODACTYLA:—(*a.*) Coryphodontidæ:—*Coryphodon.* (Fig.: *World*, 290.) — (*b.*) Palæotheridæ. (Hux., 212):—*Palæotherium.* (L. 497; Daws.: *Story*, 247; Fig.; *World*, 282-3.) — (*c.*) Tapiridæ:—*Lophiodon, Hyracotherium,* etc. — (*d.*) Suidæ:—*Chœropotamus.* — (*e.*) Anoplotheridæ. (Hux., 320):—*Anoplotherium.* (L. 498; Daws.: *Story*, 249; Fig.: *World*, 284-5.) — *Xiphodon.* (D. 517; Fig.: *World*, 285-6.)

(2.) CARNIVORA:—*Palæocyon, Hyænodon, Arctocyon, Canis,* etc.

V. Miocene Terrestrial Mammals.

1. American, (Yorktown Period—White River, Colorado, etc.) (D. 452. For white R. Fauna of Oregon, see C. X., 55-67.)

(1.) PERISSODACTYLA:—(*a.*) Equidæ. (See under Eocene):—*Mesohippus.* (D. 505; Mh. ix., 248.) — *Miohippus.* (Mh. *A.J.S.*, III., vii., 249.)—? *Anchitherium.* (Leidy, I, 64-74; C. IV., 496-7; IX., 11-14.) — (*b.*) Tapiridæ:—*Lophiodon.* (See Eoc.; Mh. ii., 36-8.) — (*c.*) Rhinoceridæ:—*Diceratherium.* (Mh. iv., 242.) — *Rhinoceros.* (Leidy, I., 79-94.) — (*d.*) Brontotheridæ. (Mh. ix., 245; xi., 335):—*Brontotherium.* (D. 507; L., 505, 506-7; Mh., v. 486; vii., 81, plates; ix., March, 1875; xi., Apr., 1876, plates.) — *Menodus.* (Pomel, *Bib. Univ. de Geneve*, x., 75, Jan., 1849.)—*Titanotherium.* (D. 506; W. 208; Leidy, I., 72-8; II., 389; Mh. ii., 35.) — *Megacerops.* (Leidy, III., 239, 335.)

(2.) ARTIODACTYLA:—(*a.*) Suidæ:—*Elotherium.* (Leidy, I., 57-66; II., 388; III., 320; Mh. ii., 39; C. V. 27.) — *Dicotyles.* (Leidy, II., 384; III., 319.) — (*b.*) Oreodontidæ. (Leidy. III., 199):—*Oreodon.* (D. 507; L. 506; Leidy, I., 29-55; III., 201, 318.) — *Agriochœrus.* (Leidy, I., 24-8; III., 319.) — (*c.*) Hypertragulidæ. (C. X., 66):—*Hypertragulus.* (C. IV., 502; V., 26-7.) — *Leptomeryx.* (Leidy, II., 165, 383.) — (*d.*) Tragulidæ. (Hux., 326):—*Hypisodus.* C. IV., 501.) — (*e.*) Camelidæ:—*Poebrotherium.* (Leidy, I., 19-24; II., 141; C. IV., 498; V., 24; X., 59.)

(3.) PROBOSCIDEA:—? *Mastodon.* (Leidy, II., 396.)

(4.) INSECTIVORA:—*Herpetotherium.* (C. IV., 465.) — *Embassis.* (C. IV., 468.)

(5.) RODENTIA:—*Palæocastor.* (Leidy, II., 338-40, 406.) — *Sciurus.* (C. IV., 475.)

(6.) CARNIVORA:—*Drepanodon* (*Machærodus*). (Leidy, II., 54-64, 367; C. IX., 9-10.) — *Hyænodon.* (Leidy, *P. A. N. S.*, 1853, 93, 392-3; II., 38-48, 369.) — *Dinictis.* (Leidy, II., 64-8.) — *Canis.* (C. IV., 505-7; C. VIII., 301; IX., 8-9.)

(7.) PRIMATES:—*Menotherium.* (C. IV., 510; V., 22.) — *Laopithecus.* (Mh. ix., 240.)

2. Foreign. (D. 518, 519-20.)

(1.) Ungulata:—*Anchitherium.* — *Hipparion.* — *Hippotherium.* — *Equus.*— *Sus.* — *Hippopotamus.* — *Anoplotherium.* — *Camelopardalis.* — *Antilope.* — *Sivatherium.*

(2.) PROBOSCIDEA:—*Mastodon.* (Fig.: *World*, 300-6.) — *Elephas.* (L. 499; Daws.: *Story*, 254.) — *Dinotherium.* (D. 518; L. 498; Daws.: *Story*, 251-3; Ag.: *Sk.*. 189; Fig.: *World*, 298.)

(3.) INSECTIVORA:—*Erinaceus.* — *Talpa.*

(4.) CARNIVORA:—*Machærodus.* (L. 500; Daws.: *Story*, 250; Leidy, I., 94-9.) — *Felis.* — *Hyæna.* — *Canis.* — *Viverra.* — *Mustela.*

(5.) Primates:—*Pliopithecus.* — *Dryopithecus, Mesopithecus.* (Fig.: *World*, 307.)

VI. Pliocene Terrestrial Mammals.

1. American (Sumter Period. — Loup Fork of Platte, the Niobrara, etc.) (D. 492.)

(1.) Perissodactyla:—*Protohippus.* (Leidy, II., 274-9, 401; III., 248; C. III., 523-8; V., 15-9; VIII., 322; Mh. II., xlvi., 374; vii., 251, 253.) — *Hipparion.* (D. 506; Leidy, II., 280-92, 401; III., 247-8; C. IV., 522; V., 11; VIII, 321.) — *Pliohippus.* (Mh. *A.J.S.*, III.,vii. 252.) — *Equus.* (Leidy, II., 399-400; III., 321-2; Mh. II., xlvi., 374. — *Aceratherium.* (Leidy, II., 220-8, 390; C. IV., 520.) — *Rhinoceros.* (Fig.: 316; Leidy, II., 228, 390.) — *Dicotyles.* (Mh. ii., 42.) — *Platygonus.* (Mh. ii., 40-2.) — *Merychippus.* (C. V., 19; VIII,, 324.) — *Dicrocerus*, Lartet. (C. VIII., 346-60.)=*Merychodus.* (Leidy, II., 162-5. 382; III., 318; C. III., 531.)= *Cosoryx.* (Leidy, II., 173, 183; C. *Rep. Vert. Foss. N. Mex.*, 16.) — *Procamelus.* (Leidy, I., 147; II., 147-57; III., 258-9, 317; C. IV., 529-30; V., 20; VIII., 325), etc.

(3.) PROBOSCIDEA:—*Elephas.* (Leidy. II., 251-6, 397-9.) — *Mastodon.* (Fig.: *World*, 314; Leidy, II., 240-51, 392-7; C. IV., 531; VI., 225-7; VIII., 306-16.)

(4.) EDENTATA:—*Morotherium.* (Mh. xii., 61)

(5.) RODENTIA:—*Castor, Palæocastor, Hystrix, Taxidea, Arctomys*, etc.

(6.) Carnivora:—*Felis.* (Leidy, *P. A. P. S.*, 1852, 261; *Trans. A. P. S.*, 1852, 322; II., 365-6.) — *Canis.* (Leidy, II., 28-30; C. V. 11; VII., 301; Allen, *Am. Jour.*. xi,, 49.)

2. Foreign. (D. 519, 520):—*Elephas, Mastodon, Pithecus, Semnopithecus, Machærodus, Putorius, Ursus, Lepus, Arctomys, Arvicola*, etc.

VII. Quaternary Terrestrial-Mammals.

1. American. (D. 565-71; L. 542-7; Foster: *Prehistoric Races of U. S.*, 80.)

(1.) PERISSODACTYLA:—*Equus. Tapirus.* (D. 567.)

(2.) ARTIODACTYLA:—*Dicotyles.* (Leidy, II., 384.) — *Ovibos.* (Leidy, II., 373-4), and most modern genera.

(3.) PROBOSCIDEA:—*Elephas*, 2 sp., and *Mastodon*, 1 sp.

(4.) EDENTATA:—*Megatherium.* 2 sp. — *Megalonyx*, 5 sp. — *Mylodon*, 4 sp. — Glyptodon, 1 sp. (D. 520. 569; L. 545, 546, 547.)

(5.) RODENTIA:—*Castoroides* and most modern American genera. (D. 567.)

(6.) CARNIVORA:—*Felis, Ursus, Machærodus, Galera.*

2. Old World Species. (D. 563-5; L. 541, 547; Dawkins: *Q. Jour. Geo. Soc.*, xxv., 192, 1869, and xxviii., 410, 1872; Rau: *Early Man in Europe*, 23-30; Lubbock: *Prehistoric Times*, ch. ix.)

XVIII. THE ALPS AND THE GLACIERS.

On Glaciers, see AGASSIZ: *Systeme Glaciaire;* CHARPENTIER: *Essais sur les glaciers;* TYNDALL: *Hours of Exercise in the Alps;* RÉCLUS: *The Earth*: pp., 162-221; Payot: *Guide itineraire au Mont Blanc;* CHAMBERLIN: *Rep. Geol. Wis.*, 1876; DANA: *Man.*, 675-80; LECONTE: *Elem.*, 43-64; LYELL: *Principles*, 224-8. On the *Glacier of the Rhone traced to Lyons*, see Bibliotheque, Univ., 1870, xxxviii., 118, and *Bul. Soc. Geol. de France*, 1869, xxvi, 360. On the Glaciers of Norway, *C. de Seue, La Neve de Justedal et ses Glaciers;* 1870.

I. Geography of the Alps. (Lantern Views.)

1. Regions of the High Alps.
2. Alpine Regions and Passes.
3. The Bernese Oberland (90 miles square.)

II. Geology of the Alps.

1. General Structure of the Alps.
2. Section from Lucerne to Como.
3. Tunnel under Mont St. Gotthard.

III. Perspective Views of the Alps.

1. Mont Blanc Range from Geneva.
2. The Bernese Oberland from Bern.
3. Mont Blanc from St. Martin.
4. Les. Ouches, Mont Maudit and Pic du Midi.
5. Chamonix and the Mont Blanc from above Chamonix.
6. Mont Blanc and the valley of Chamonix, from the Flégère.
7. Mont Blanc, from the Brévent.
8. The Jungfrau from Interlaken.
9. Valley of Lauterbrunnen.
10. Valley of Lauterbrunnen and the Gletscherhorn.
11. Falls of the Staubbach.
12. The Breithorn, from the Mürren.
13. Panorama from the Mürren.
14. The Jungfrau from the Wengern Alp.
15. The Jungfrau and hotel from the Summit of the Wengern Alp.
16. The Wetterhorn from Grindelwald.
17. The Matterhorn and Gorner Glacier, near Zermatt.
18. Gorge of the Tamina at Pfeffers.

IV. The Pinnacled forms of Alpine Summits.

1. Aiguille de Charmoz, from Montanvert.
2. Aiguille de Charmoz, from the Chapeau.
3. Aiguille du Dru, from Montanvert.

4. Glacier des Bois and Aiguille du Dru.
5. Grands Mulets and Aiguille du Midi.

V. General Views of Glaciers.

1. Mer de Glace, from the Flégère.
2. Mer de Glace, from Montavert.
3. Eiger Glacer, Eiger and Monk, from the Wengern Alp.
4. Church and Glacier of Grindelwald.
5. Glacier of Rosenlauï.
6. Glacier of the Rhone.
7. Aletschhorn and Middle Aletsch Glacier from the Egischhorn.

VI. Terminations of Glaciers.

1. Arch of Ice at Source of the Arveiron.
2. Same from a different position.
3. Bridge of Ice, Glacier of Langthal, Oetzthal in Tyrol.
4. Another Bridge of Ice, Oetzthal.
5. Glacier of Langthal—ice-blocks at termination.
6. Source of the Lütschine.
7. Vault of Ice, Glacier of Rosenlauï.
8. Terminal Precipice, Gorner Glacier, Zermatt.
9. Source of the Rhine, (Hinter Rhine,) from the Rheinwald or Zapport Glacier.

VII. Phenomena of Transportation by Glaciers.

1. Village and Glacier of Argentière, showing lateral moraines.
2. Hotel Montanvert, showing moraines of Glacier of Nant Blanc.
3. Bridge des Gaillants, showing moraines of Glacier des Bossons.
4. Erratic Blocks on the Glacier of the Aar.
5. Oberaarhorn and Glacier of Viesch, from Eggischhorn, showing Median Moraines.

VIII. Glacier Motion and its Consequences. (Ref. *supra*, and Lect. XIX., III., 2.)

1. Summit of Mont Blanc, showing Firn-fields.
2. The Weissthor, the Cima of Jazzi and Monte Rosa.
3. Diagram of Crevasses, showing their cause.
4. Incipient Crevasses at entrance of "Junction" in ascent of Mont Blanc.
5. The Junction and the Plateau, showing crevasses more advanced.
6. The "Difficult Passage," Mer de Glace.
7. Another Difficult Passage.
8. Mer de Glace, from the "Mauvais Pas"—Chaos of Ice.
9. Grand Pyramids, Glacier des Bois.
10. Grand Pyramids of Ice, Glacier of Gaisberg, Oetzthal.
11. Aiguilles, Glacier des Bois.

12. Crevasse in Glacier of Grindelwald.
13. Glacier des Bossons, from Pierre Pointue.
14. Séracs before the "Junction."
15. Ladder Passage, departure from the Junction.
16. Passage of the Horizontal Ladder, Junction.
17. Aiguilles des Bossons, and the Side Wall.
18. Ladder Passage, Wall of Ice, before the Grands Mulets.
19. Precipices of Ice and Snow above the Grands Mulets.

IX. Causes of Catastrophes.

1. Great Crevasses below the Dome du Gôuter.
2. "Grande Crevasse" at the Grand Plateau, Mont Blanc.
3. Great Crevasses, impracticable passage, "Petites Montées."
4. Disaster from an Avalanche, August 20, 1820.

XIX. THE REIGN OF ICE.

GEIKIE: *The great Ice Age;* NEWBERRY *Geol., Ohio*, ch., xxx. (vol. ii), and iii., 27; *Annals of N. Y. Lyceum of Natur. Hist.*, ix., June, 1869; *Proc. Boston Soc. N. Hist.*, x., May, 1862; N. H. Winchell, *Pop. Sci. Mon.*, June and July, 1873; *Am. Jour. Sci.*, III, i., 15-9; J. J. Dana, *Am. Jour. Sci.*, III., i., 1, 125; ii., 233, 326; E. Andrews, *Am. Jour. Sci.*, II., xlviii, 172; Jos. Leconte, *Ancient Glaciers of the Sierras, Cal. Acad. Sci.*, 16 *Sep.*, 1872; *A. J. S.*, III., v. 325-42.

I. Familiar Drift Phenomena.

1. Incoherent surface accumulations. (D. 527, 529; L. 514-6.) — Sands, pebbles, boulders, clays. (L. 514-6; W. 220 — "Hog-backs" and surface configuration.
2. Smoothed, striated and furrowed rocks. (D. 530: L. 516; W. 215, 217-8; Newberry: *Geol. of Ohio*, ii., 12-9.)
3. Fiords. (D. 533; L. 534; W. 220.) — Old river channels sometimes deeply buried. (D. 552; W. 219-20; Newberry: *Geol. O.*, ii., 12, iii., 27; *Boston S. N. H.*, x, May, 1862; E. Hitchcock: *Geol. Vt.*, i., 215.)
4. All these phenomena connected together.

II. Sketch of Continent at End of Tertiary Time. (W. 213.)

1. Its Geographical Extent and Form.
2. Its Topographical and Hydrographical features.
3. Its Forest growths.
4. In many respects similar to the modern continent. (D. 525; W. 210.) — But it was an ancient and wasted surface. — Sub-aërial disintegration of rocks. (W. 221; also in Harper's *Geol. Rep. Miss.*, 1857; W. *Brazil in the Reign of Ice*, College Courant, June 4 and 11, 1870; Pumpelly, *Am. Jour.*, xviii., 142, etc.) — General doctrine of continental wastage.

III. How the preglacial Continent was Renovated.

1. Northern Elevation and increasing cold. (D. 539-40, 541; W. 214.) — Union of lands previously separated.
2. Glacier formation, growth, movement and effects. (On Glacier motion, see further, Mosely, *Proc. Roy. Soc.*, xvii., 202; *Phil. Mag.*, Aug., 1871; Croll, *Phil. Mag.*, March, 1869; Ball, *Phil. Mag.*, July, 1878; *A. J. S.*, III., i, 268; Mathews, *Alpine Jour.*, Feb, 1870); John Aitken, *Nature*, 13 Feb., 1873; *A. J. S.*, III., v., 305.
   (1.) Reminiscence of Alpine glaciers. (D. 675 8; L. 43.)
   (2.) Tremendous effects of a continental glacier. (D. 538; W. 218-9.) — Prostration of forests. — Plowing and removal of disintegrated rock-surfaces. — Smoothing and striation of hard rocks. (D. 538.) — Digging of some lake-basins. (D. 539; W. 225.) — Filling of old river-channels and lake outlets. (539; W. 219-20, 225.) — Desolation in nature. — Greenland a modern picture of continental glaciation. (D. 538.)
3. Thickness of the Continental glacier. (D. 537; *Am. Jour.*, v., 1873; L. 527.) — Limited by the thawing influence of heat escaping from the Earth. (Matthew, *Canad. Nat.*, vi., 96.) See also Dana, *ut sup.* and *A. J. S.*, III., v., 217.
4. Extent of the ancient glaciers, and directions of the ice-streams. (D. 528, 531, 537; L. 519, 526-7.) — Movement south-west along the upper valley of the St. Lawrence, Lakes Ontario and Erie, and the Maumee river. (D. 537; Gilbert, *Geol. Ohio*, i., 540-4, map); Newberry, *Geol. Ohio*, ii., 50-3, map.) — The Colorado valley supposed not glaciated. — Nor the slopes of the Rocky Mts. in the U. S. (D. 538; Hayden, *Ann. Rep.*, 1874, ch., iv.) — The western glaciers local. (King, *Geol. 40th Par.*, i. 460-1. But see R. Brown, *Am. Jour.*, II., l., 318-24.) — Glaciers in southern Colorado. (Endlich, Hayden, *Ann. Rep.*, 1875, 216-26. — Glaciation in Foreign Countries. (D. 532; L. 530-2; L. Ag.: *A. J. S.*, III., iv., 135; C. F. Hartt, *A. J. S.*, III, i., 294, Brazil.)
5. Supposed interglacial epoch. (D. 561; L. 534; S. V. Wood, *Geol. Mag.* Apr., 1872; Geikie, *Geol. Mag.*, viii., ix.; *A. J. S.*, III., iv., 231.)
6. A gradual subsidence. (D. 551, 555; L. 521.) — Dissolution of the ice-fields. (W. 222.) — Work of the torrents. (D. 553; W. 222.) — Freight of sediments. (D. 553.) — Renovation of southern areas. (D. 553; W. in Harper's Rep. on Miss., 1857, 317; W. 222-3. Compare Tuomey, *Ala. Geol. Rep.*, 1849, 2, 116, 142.) — Stumps of the glaciers still existing. (King, *Geol. 40th Par.*, i., 462; *Am. Jour.*, i., 157; Davidson, *Proc. Cal. Acad. Sci.*, iv., 1871, 161; J. Muir, *Overland Monthly*, Dec., 1872; *A. J. S.*, III., v., 69; Leconte, *Am. Jour.*, iii., 125; v., 325; x., 126; *Proc. Acad. Nat. Sci.*, Cal., iv., (pt. v.,) 259.) — Ice-wells:—Vermont.

(Hitchcock, *Geol. Vt.* i., 192.) — Oswego, N.Y., (*Am. Jour.*, I., xxxvi., 104.) — Ice-mountain in Va., (*Am. Jour.*, I, xlv., 78.) — In Wallingford, Vt. (*Am. Jour.*, I., xlvi., 331.) — Ice-caverns in Russia. (*Geol. Russia*, i., 186; Lippincott's *Gazetteer*, Art., *Yakotsk*.

7. A continental submergence generally supposed. (W. 228; C. H. Hitchcock, *Proc. A. A. A. S.*, 1871; *A. J. S.*, III., ii., 207.) — Not established for the Cordilleran region. (King, *op. cit.*, i., 466.)
8. A slow emergence and assorting of materials. (L. 524; W. 229.) — The assorting possibly the work of glacier-torrents, without submergence.

XX. POST GLACIAL HISTORY.

Newberry: *Geology of Ohio*, ii., ch. xxx; Dana, *A. J. S.*, III., v., 198.

I. Reappearance of the preglacial Flora.

1. Floral migrations under secular changes of climate. (D. 532, 543, 599.)
2. Return of preglacial types from the south. — Arctic or glacial types still lingering on mountain summits.

II. Migrations of Faunas. (D. 542.) — A South American Fauna in the United States. (D. 569. Also Lect. XVII., VII., 1, (4).)

III. Early Condition of the Great Lakes.

1. Their present relations as to Altitude.
2. Former altitudes. (W. 241-3; 246; L. 521.) — Terraces. (W. 246-7; L. 521-2; Gilbert, *Ohio Geol. Rep.*, i., 540-4.) — Rock erosions. (W. 246-7.)
3. Former Geographical Extent. (D. 552; W. 241; W. *Michigan*, 77.) — Low lacustrine borders. (D. 552.)
4. Ancient outlets and connections. (Newberry, *Geol. Ohio*, ii., 12-9.)
   (1.) By Little Bay de Noquet. (W. *Michigan*, 28-9; N. H. Winchell, *A. J. S.*, i. 19.)
   (2.) By Green Bay, Lake Winnebago and the Wisconsin chain. (N. H. Winchell, *A. J. S.*, i., 15-9.)
   (3.) By the Illinois river. (D. 540, 552, 553; E. Andrews, *Trans. Chic. Acad. Sci.*, ii., 14.)
   (4.) By the Maumee river. (D. 540, 552; Gilbert, *A. J. S.*, i., 342-4.)
   (5.) A channel across the Lower Peninsula of Mich. (W. *Mich.*, 15-6.)
   (6.) Submerged outlets of the Connecticut and Hudson rivers. (D. 423, 540.)

IV. Subsidence of Lakes.

1. Removal of Barriers of the Great Lakes. (W. 542.) — The Niagara barrier, its effect, and the result of its degradation. (W. 235.)

2. Desiccation. — Quaternary lakes of the far west. (King, *Geol. 40th Par.*, i., 490; Stevenson, Wheeler, *Rep.*, iii., 453-71. — Lake Bonneville.) Gilbert, *Wheeler Rep.*, iii., ch. iii.; Howell, *ib.*, 250-1; Hayden: *Rep., Wyom.*, 1870, 72-3; *Pacif. R. R. Rep.*, ii., 97; King, *Geol. 40th Par.*, i., 490-504.) — Lake Lahontan. (King, *Geol. 40th Par.*, i., 504-29, maps.) — Coronado's Lakes. (Endlich, *Hayd. Rep.*, 1875, 147-8.) — Other extinct lakes. (Hayden: *Ann. Rep.*, 1874, 48.) — Deposits of Marl and Peat. W. 237; King, *Geol. 40th Par.*, i., ch. vi.)

XXI. POST-GLACIAL HISTORY. (Continued.)

I. Aqueous Erosions.

1. The recession of Niagara Falls. (D. 553; W. 235, 244; Hall, *Geol. N. Y., 4th Dist.*, 389; Foster: *Prehist. Races* U. S., 376-7.) — Data. (W. 245.) — Consequences.
2. Recession of the Falls of St. Anthony. (N. H. Winchell, *Geol. Minn.*, 1876; *Q. J. G. S.*, Lond, Nov., 1878, 886-900; Southall: *Epoch of the Mammoth*, ch. xxiii.)
3. Deepening of river gorges. (L. 529; W. 344.)
4. Changes of River channels. — The Ohio. (D. 553.) — The Hoang-Ho. (Pumpelly, *Smiths. Cont.*, xv., Art. iv.; *Am. Jour.*, II., xlv., 219; Bickmore, *Am. Jour.*, II., xlv., 209; Martin, *Am. Jour.*, II., xlvii., 100; Richthofen: *China*, 12, 85-7.) — Mississippi Bayous. (Ly.: *Prin.*, 215-7.) — The Rhine. (D. 556.) — In Vermont. (Hitchc.: *Geol. Vt.*, i., 215.)
5. Dissolution of Sea-Coasts. (L. 32-6.)

II. Fluviatile Formations. — Alluvium. (D. 649; L. 22-3, 522-4.) — Deltas. (D. 651; L. 24-7; Ly.: *Prin.*, 208-13.) — Mississippi Delta. (Ly.: *Travels*, 2d vis., ii., ch. xxi; Humphreys and Abbott: *Rep. Miss. River.*) — Bars. (D. 660; L. 30.) — Rafts. (Ly.: *Prin.*, 213.) — Terraces. (D. 558-9.) — Mud-lumps. (Hilgard, *A. J. S.*, III., i., 238, 356, 425.)

III. Sandy Deserts and Dunes. (Marsh: *Man and Nature*, ch. v.)

1. Drifting sands. (L. 520.) — Dunes of Western Europe. (Marsh: *loc. cit.*) — Of Africa. (Ly.: *Prin.*, 702; Reclus, 91.) — Of Lake Michigan. (W. *Michigan*, 13.) — Of Nebraska. (Aughey, *Hayd. Rep.*, 1874, 259.)
2. The Sahara. (Réclus: *Earth*, 90-5.) — An ancient sea-bottom. — Some portions still below the Mediterranean. — Project of inundation. (*Internat. Rev.*, iv., 138-9; *Nature*, Apr. 3, 1879, 509; Scribner's *Month.* ; *Engineering and Min. Jour.*)

3. Deserts in Poland. (Naumann: *Geognosie*, ii., 1173. — Arabian Nefouds. (Réclus: *Earth*, 95.) — Cobi. (Réclus, 95; Richthofen: *China.*) — Sandy Steppes of Tartary. (Réclus: *Earth*, 87-9.) — Grandes Landes of Gascony. (Réclus: *Earth*, 81.)

IV. Campestral Formations.

1. Prairies, grassy steppes, pampas, llaños, puszta. (W. 264; Réclus: *Earth*, 85, 98-101; Humboldt: *Aspects of Nature*, Am. ed., 25-165.) — Tundras. (Réclus, 86.) — Buried Mammoths. (W. *N. Y. Daily Trib.*, 17 Aug., 1878.) — Bogs. (Réclus: *Earth*, 83, 413-8; Ly.: *Prin.*, ch. xlvi.; Hunt: *Can. Nat.*, II., i., 426.) — Peat and Muck. (S. W. Johnson, *Trans. Conn. State Agrie. Soc.*, 1857 and 1858.)
2. Loess-covered surfaces. (Pumpelly, *Amer. Jour.*, xviii., 133; Aughey, *Hayd. Rep.*, 1874, 245-50); Richthofen: *China.*

V. Post-glacial Volcanoes. (L. *Am. Jour.*, xviii., 35.)

VI. Coral Structures. — Polynesian Coral Islands. (D. 583.) — The peninsula of Florida. (W. 231.)

XXII. RELICS OF PRIMEVAL MAN.

Rau: *Early Man in Europe*, 1876; Lubbock: *Prehistoric Times*, 3d ed., London, 1872; Figuier: *Primitive Man*, Am. ed., 1870; Vogt: *Lectures on Man*, London, 1864; Foster: *Prehistoric Races of the U. S.*, Chicago, 1874.

I. Primeval Man Known to Inductive Science chiefly through European Relics.

II. Primeval Man in Europe. (L. 561, etc.)

1. Historical allusions. (Homer: *Odyss.*, ix., 113-4, 108, 122, 124, 160, 167, 244, 125-128, 271-275; Hesiod: *Theog.*, 133, 139; Aeschylus: *Prometh.*, 462-4; Aristotle: *Politica.*, l. i., c. 1.; Plato: *Leges;* Pausanias: *Descr. of Greece*, l. viii., c. 1, § 2, 5, 6; l. v., c. 17, § 1, 3; l. x., c. 17, § 2; Diod. Sic., l. v., c. 65; Virgil: *Æneid*, viii., 314-18; Tactitus: *Germ.*, c. 46.)
2. Race affinities of these men. (Vogt: *Lect.*, 370-93.)

III. Archæological Discoveries. (L. 563, etc.; W. 352.)

1. Caverns and Rock-shelters. (D. 574, 575, 576; L. 536-9, 563-5; Rau, ch. ii., iv.; Lubbock, ch. x.; Fig., 56-82, 85-90. Dawkins: *Cave Hunting.*)
   (1.) Where explored. (Rau, ch. ii., iv.)
   (2.) What they contain. (Rau, ch. ii., iv.)
2. River-Drifts. (Rau, ch. i.; Lubbock, ch. xi.)
3. Loess and Moraines.
4. Volcanic Tuff.
5. Peat Bogs. (L. 539, 542.)

6. Kitchen Middens. (D. 577; L. 566; Rau, ch. v.; Lubbock, ch. vii.; Fig., 129-34.) — On the Pacific Coast. (Schumacher, *Bul. Hayd. Surv.*, iii., 27-56.)
7. Megaliths and Tumuli. (Lubbock, ch. v.; Fig., 184-207.) — Cist-vaens, Barrows, Dolmens and Cromlechs.
8. Lake Dwellings. (D. 576; L. 566: Lubbock, ch. vi; Fig., 135-7, 215-30.) — What they are. — What they yield. (Fig., 240-87.) — Crannoges. (D. 576; Lubbock, 177; Fig., 230-1.) — Terramares. (Fig., 232-9.)
9. Parallel facts supplied by modern savages. (Lubbock, ch. xiii-xv; *Origin of Civilization.*)

IV. Intrepretation of the Facts.

1. Divisions of prehistoric time. (D. 574; L 561; Lubbock, ch. i.)
   (1.) Ages:—Stone. (Lub., ch. iv; Fig., 1-202.) — Bronze. (Lub., ii-iii; Fig., 205-93.) — Iron. (W. 353; Fig., 297-332.)
   (2.) Stone Age sub-divided into three epochs.
   (3.) Cannot be used for chronometric purposes. (W. 353; Rau., 12.)
2. Geological conditions in the Stone Age. (W. 361.)
3. Characters of Prehistoric Europeans. (Rau, ch. iii-iv; Lub., ch. x.)
   (1.) Physically. (Rau, 81; Lub., 337-40; Fig., 112-6; Vogt, 370-93.)
   (2.) Socially and Intellectually. (W. 363-5; Rau, 66-70, 83, etc, ch, v; Lub., 586 Fig., 128, 137-83, 258-70.)
   (3.) Æsthetically. (W. 358, 355-6; Rau, 65-6, 71-9, 85-6, 103-5, Lub., 29-44, 335-5.)
   (4.) Religiously. (W. 366; Fig., 280-3.)

V. Primeval Man in America. (Lub., ch. vii; Foster, *op. cit.;* Squier and Davis: *Ancient Monuments Miss. Val.;* Lapham: *Antiquities of Wis.:* Haven: *Archæology of the U. S.*)

1. Mounds and Tombs. (Lub., 267-77; Fost., ch. iii, v, vi, viii, x.)
2. Earth-works. (Lub., 259-63; Lapham: *Antiq. Wis.*)
3. Mining Hammers. (Fost., ch. vii.)
4. Shell-heaps. (Fost., ch. iv.)
5. Remains beneath lava in California. (Fost., 52-6. Lect. XLVII.)
6. Mesa Ruins or Cliff-Dwellings. (Ives: *Explor. Col. Riv.*, 119, Moquis; Jackson, *Hayd. Rep.*, 1874, 369-81, plates; *Hayd. Rep.*, 1875, 12, 23-4.)

XXIII. METHOD OF CONTINENTAL DEVELOPMENT.

DANA, *Proc. Am. Assoc.*, 1856, pt. ii., 1-25, chart; *id.*, 1855, 1-36; *Manual Geol.*, 389-90, 591; *Am. Jour. Sci.*, II., xxii., 335; WINCHELL: *Sketches of Creation*, ch. xxvii.; KING: *Geol. 40th Parallel*, i., ch. vi. and viii.; GEIKIE, *Proceed. Roy. Geograp. Soc.; Popular Sci. Monthly*, Sep., 1879. On the *Geological History of the Gulf of Mexico*, see E. W. Hilgard. *Proc. A. A. A. S.*, 1871, 222; *A. J. Sci.*, III., ii., 391.

I. Primordial Wrinkles the Germs of Land-Masses. (Lect. XXXIX.) — Cause of wrinkles. — Their location. — The system of contraction and upheaval.

II. The Continent of Palæozoic Time.

1. Composed of Archæan sediments. (D. 161.) — These the ruins of an older, unknown land.
2. Location and Form of the Palæozoic Continent.
   (1.) The Laurentian limb. (D. 148.) — Detached insular Laurentian exposures. (D. 150; Lect. III., III., 2. Also Irving, *A. J. S.*, III., v., 284, map; J. H. Eaton, III., v., 444, map; Hind, A. J. S., II., xlix, 347-55, in Nova Scotia.)
   (2.) The Cordilleran limb. — Consisted of emerging peaks of the Cordilleran ranges from the Colorado to the Humboldt ranges. (King, 40*th Par.* I., ch. I., *id.*, 534; Newb., *Ives Color. Exped.*, 47; Peale, *Hayd. Ann. Rep.*, 1875, 68-9.) — Thought by King to have been a continuous land area before Cambrian Time. (King, 40*th Par.*, i., 533, 534, 729-30. Compare Newb., *Ives Col. Exp. Exped.* and Peale *Hayd. Ann. Rep.*, 1875-68.) — The Nevada Mass continued continental. (King, 40*th Par.*, i., 731.) — But subsided at end of Palæozoic. (King, 40*th Par.*, i., 732.)
3. Origin of sediments and supposed subsidence of Appalachian region. (D. 161, 251; L. 254-5.) — This implies a land-region to the north-east of the present continent.
4. Great thickness of Palæozoic sediments (40,000 ft.) along the border of the Nevadan continent. (King, 40*th Par.*, i., 731.) — Great subsidence of Palæozoic sea-bottom. (King, 732.)
5. The configuration of America due to the topography of the Precambrian continent. (King, 40*th Par.*, i., 533, 751.)
6. Europe mostly submerged during Palæozoic Time. (Geikie, *Pop. Sci. Monthly*, Sep., 1879, 599. — The Northern land of Europe and the Northern Ocean.

III. The Continent of Mesozoic Time. (D. 481.)

1. Composed of Palæozoic and Archæan sediments.
2. Its duplex constitution.
   (1.) The Laurentian limb. — Its south-eastward and south-westward growth. (D. 3:3, 481.) — Comparative completeness.
   (2.) The Cordilleran limb. — The Palaeozoic sea becomes dry land forming the Great Basin and the Wahsatch. (King, 40*th Par.*, i., ch. ii,, Map; *id.* 536-7, 731-2 759; D. 520.) —. And the Nevadan Continent sinks beneath the sea. (King, 537, 732.) — Distinction between subsidence of a lightened continental mass and of a loaded sea-bottom. — The latter gradual, the former cataclysmic. (King, i., 732.) — The western shore of this continent trended meridionally, the eastern, retreated south westward into Arizona. (King, i., 733.) — Numerous, and some extensive, islands in the Mesozoic ocean, along the Rocky mountain region.
3. The great intercontinental ocean between the Wahsatch and the Mississippi valley. (D. 481, 520; King, i., 537, 733.)
4. Europe still mostly submerged. (D. 481.) — Land growing southward. (Geikie, *Pop, Sci. Mon.*, Sep., 1876, 601.)
5. South America more extensively submerged.

IV. The Continent of Cænozoic Time. (D. 520.)

1. Composed of pre-cenozoic sediments.

2. The twin areas connected. — Uplift of Rocky Mountain region and a portion of the Great Plains. (King, 40th Par., i., 360; ch. iv., and map; D. 480.)
3. The great mediteranean seas or "Tertiary lakes" of North America. (Newb., *Hayd. Rep. Wyoming*, 1870, 329-39; Hayden: *Ann. Rep.*, 1872, 33; *id.* 1874, 47.)
   (1.) Residual portions of the Mesozoic intercontinental ocean. — Shifted and enlarged, however, by regional subsidences. (King, i., 754-6.)
   (2.) Their locations, extent and names. (King, i., 458; Lect. XVI.)
4. The mediterranean seas of Europe. (D. 480.)
5. The condition of South America. — The Andes under water. (D. 480.)
6. The final uplift and consummation. — But very gradual.

V. Unity of Method in Continental Growth. (D. 29-38.)

1. Ultimate forms foreshadowed from the beginning. (D. 147, 160, 393-4; King, 40*th Par.*, i., 751.) — Two great water sheds on the Laurentian limb, each with two branches. (D. 24, 160.) — The northern branches diverge, the southern converge. — The Cordilleran limb also grew from its Archæan germ.
2. To what extent have continents and oceans exchanged places? (D. 160, 250.)
   (1.) The old idea of general exchanges.
   (2.) The later idea of no exchanges.
   (3.) The truth lies between. — Some subordinate exchanges. (King, i., 731-2, 746, 755, 756.) — Still, the Atlantic and Pacific have never been continental.

XXIV. MOUNTAIN-BUILDING.

MALLET: (See references, Lect. XXVI and Part II); HUNT: *Chemical and Geological Essays*, 241-82, 328-48; HALL: *Palæontology of New York*, iii., 1859, Introduction, 57-96: LECONTE: *Elements of Geology*, 1878, 240-60; *Am. Jour. Sci.*, III., iv., 354 and 460-72; KING: *Geology of the 40 h Parallel*, i., ch. viii., Orography; GILBERT: *Orography*, in Wheeler Report, Vol., iii., ch. i.; WHITNEY: *Mountain Building*, in N. A. Review; H. D. ROGERS: *Geology of Pennsylvania*, Vol., ii., pt. ii., 885-941; VOSE: *Orographic Geology*, Boston, 1866. 8vo., 136 pp.; BABBAGE: *Proc., Geol. Soc.*, London, ii.; SIR JOHN HERSCHEL: *Proc. Geol. Soc.*, London, ii.; NAUMANN: *Geognosie*, I., 337-633.

Two distinct origins of Mountains. — By upheaval and by relief.

I. Mountains of Upheaval.

1. Primordial wrinkling of the terrestrial crust.
   (1.) Cause of the wrinkling. (D. 739; L. 240, 252-4; see further, Part II.)
   (2.) Location of some primitive wrinkles.
      (*a.*) Laurentian nucleus. — Appalachian. (D. 150.) — Cordilleran, especially between lon. 105° and 115° 30'. (King, i., ch. i., and map. See also Lect. XXXIII., II., (2).) — Scandinavian. (D. 151.)
      (*b.*) Perhaps Caribbean, Lemurian, Indian.
   (3.) These not originally lofty mountain masses.

2. Progressive development and wear of these wrinkles.
   (1.) Source of materials for sedimentation.
   (2.) Deposition along coast-borders. (L. 254-6.)
   (3.) Parallel ranges developed successively coastward. (L. 257.)
   (4.) Simple and complex mountain folds. (L. 242-3; Whitney: *Geol. Cal.*, 121; Comstock, in Jones' *Rep. N. W. Wyom.*, 139-Wind R. Mts.) — The lowest rocks exposed along the eroded crest. (L. 242-5.)
   (5.) Indications of successive uplifts. — Section across the Adirondacs. — In the Rocky Mountains. (*Wheeler Rep.*, iii., 499.)
   (6. High inclinations and overturns of strata.
      (*a.*) Appalachians. (D. 396; Safford: *Geol. Tenn.*, 185, 190.) — Green Mts. (D. 213.)
      (*b.*) Elk Mts. Col. (D. 740; L. 176; Peale, *Hayd. Rep.*, 1873, 256, plates xvii., xviii.; Holmes, *Hayd. Rep.*, 1879, 68-71, and maps and chart of sections.)
      (*c.*) Sangre de Cristo Mts., Col. (Endlich, *Hayd. Rep.*, 1875, 121-3, plates, 125.)
      (*d.*) In foreign countries. (Murchison: *Siluria*, 96, Malvern Hills, 501, Alps. See also Rogers: *Geol. Penn.*, ii., 901-2, ideal section of Alps; and Hunt: *Op. cit.*, 328-48.)

3. The Synclinorium theory of Mountain making. (D. 748-50, 211-14, 244, 251, 275, 305; L. 252-60; Hall: *Pal. N. Y.*, iii., Introd. Comp. King, i., 731: Hunt: *Chem. and Geol. Ess.*, 49-58.) — Secular contraction of the earth pronounced inadequate. (Dutton, *Penn. Monthly*, May and June, 1876; Fisher, *Cambridge Phil. Trans.*, xii. See further, Part II.)

4. Faulting. (741; L. 258, 261, 263.)
   (1.) In Silurian rocks. (D. 214-5.)
   (2.) In the Appalachians, 20,000 feet. (D. 398-400, 647; L. 261; Safford: *Geol. Tenn.*, 142, 144, 185.)
   3.) In the Colorado Range 6,000 to 7,000 feet. (King, i., 730.) — Park Range 10,000 feet. (King, i., 730.)
   (4.) In the Unita Mts, 20,000 to 25,000 ft. (L. 242, 263; King, i., 730; Powell: *Uinta Mts.*, 12, Atlas, plates i., ii., iii.)
   (5.) Along the Wahsatch Range, 3,000 to 40,000 ft. (King, i., 44, 730, 745-6.)
   (6.) Along the Basin Ranges generally, from Salt Lake to Carson Lake. (King, i., 735 and maps, x., xi. and xii.)
   (7.) The Sierra Nevada, 3,000 to 10,000 ft. (King, i., 744.)
   (8.) Disapearance of half an anticlinal by downthrow along a fault. — Sierra Nevada, Wahsatch, Unita and other Ranges. (See foregoing references.)
   (9.) Monoclinal ridges and "Kaibab structure." (Powell: *Uinta Mts.*, 10-16; also Gilbert and Howell, in *Wheeler Rep.*, iii.; Rogers: *Geol. Penn.*, ii., 920-1.)

5. Thickness of sediments in mountains of upheaval. (D. 210, 749; L. 244, 243-6; Rogers: *Geol. Penn.*, ii., 779.) — Metamorphism. (D. 750, 400; L. 357; Hunt: *op. cit.*, 18-34: Daubrée, *Annales des Mines*, V. xvi., 155-393, Trans. *Smiths. Ann. Rep.*, 1861, 228-304.)

6. The Cordilleran chain mostly formed by upheaval. (L. 241.)

7. Vertical movements generally slow. (D. 754; L. 244; Lyell; *Prin.* 159-69; Safford: *Geol Tenn.*, 183.)

II. Mountains of Relief.

1. By erosion of horizontal or slightly tilted strata. (Rogers: *Geol. Penn.*, ii., 927-33.) — Table mountains. (D. 246; Whitney: *Geol. Cal.*, 211, 248; Powell: *Uinta Mts.*, 18.)
   (1.) Excavation of basins and valleys in such strata. — Central Tennessee. (W. 342; Safford: *Geol. Tenn.*, 97-104.) — The Cumberland Table Land. (W. 343; Safford: *Geol. Tenn.*, 66-79. — Amazonian valley borders. (Ag.: *Journey in Brazil*; Orton: *Andes and Amazon.*) — Uinta Mountain or Range. (Powell: *Uinta Mts.*; King, i., 9, 753.)
   (2.) Removal of formations along one border. (L. 249-50.) — Appalachians. (Rogers: *Geol. Penn.*, ii., 920-1.) — Many ranges in the Great Basin. (Gilbert, *Wheeler Rep.*, iii., ch. i., sec. i.) — But these perhaps faulted anticlinals. (Howell, *Wheeler Rep.*, iii., ch. viii., sec. i.; King, i., 735, iii., 45.)
   (3.) Removal along both borders. — The Catskills. — The Appalachians. (L. 241.) — Mt. Dana in the Sierra Nevada. (Lec, *Am. Jour.*, June, 1873, v. 452.)
2. By erosion along anticlinals. (D. 749; L. 246; Rogers: *Geol. Penn.*, ii., 933-6.
   (1.) Mountains of upheaval completed as mountains of relief. (D. 647; L. 246.)
   (2.) The synclinal structure in mountains. (D. 213, 748; L. 248.)
      (*a.*) Examples:—Taconic Mts. (D. 213-14, 750.) — Greylock. (D. 214.) — Green Mts. (D. 750.) — Alleghanies. (D. 398; Rogers: *Geol. Pa.*, i., 13; *ib.*, ii., 926.)
      (*b.*) Coast Range. (Whitney: *Geol. Cal.*, i., 14, 144.) — Wahsatch Range. (Hayden: *Ann. Rep.*, 1872, 16.)
   (3.) Anticlinal valleys. — Appalachians. (Rogers: *Geol. Penn.*, ii., 922-23.) — Valley of East Tennessee. (L. 246; Safford: *Geol. Tenn.*, 144. — Other examples. (Powell: *Color. River*, fig. 55; Murch.: *Silur.* 126.)
   (4.) All sculpturing the work of erosion. (L. 245-50.) — Pinnacles and Peaks:—Castle Range, Cal. (Whitney: *Geol. Cal.*, i., 33.) — Granitic pinnacles. (*ib.*, 373.) — Mt. Brewer. (*ib.*, 380-1.) — Yo Semite. (*ib.*, 407-23.) — Other Cal. peaks. (*ib.*, 424-37.) — Wahsatch Range. (King: *40th Par.*, i., 44, pl. i.) — Elk Mts., Col.) (Hayden: *Rep.*, 1874, ch. v., and maps; also, 1873.) — In Wyoming. (Hayden: *Rep.*, 1872, 47.) — Colorado valley. (Ives, *Explor. Col.*, 48, 49, 50, 52, 55, 62.) — "Needles" of the Swiss Alps. (Lect. XVIII., IV.)
3. Relief mountains not always metamorphic.

III. Types of Mountain Structure. (Powell: *Uinta Mts.*, 9-29; also *Explor. Color. R.*, ch. xi., and *Am. Jour.*, xii., 414-28, illus.)

XXV. PRINCIPAL EPOCHS OF OROGRAPHIC DISTURBANCE.

I. Chronological Arrangement.

1. Presilurian:—Laurentides. — Adirondacks. — Blue Ridge. — Highlands, from N. J. to Dutchess Co., N. Y. (D. 16, 211.) — Black Mts., N. C. — Black Hills. — Wind River Mts. (D. 390.) — Colorado, Medicine Bow, and Park Ranges. (King: *40th Par.*, i., 5, 17-42; Powell: *Uinta Mts.*, 26; Marvine: *Hayd. Rep.*, 1873, 139.) — Core of the Humboldt Range. (King, *id.*, 12, 62.) — Sawatch Range. (Hayden: *Ann. Rep.*, 1873, 49-57, 246.)

2. End of Lower Silurian. — Green Mts. in part. (D. 212-14, 305, 355, 389, 390, 392.) — Northeastern U. S. (Rogers: *Geol. Penn.*, ii., 784.) — In Europe. (D. 217.)
2. End of Devonian :—Catskill Mts. (D. 290.) — New England, Eastern Canada, Nova Scotia. (D. 289, 390)
4. End of Carboniferous :—Alleghanies. — Western portion of Great Basin, or present Nevada Plateau, with submergence of older Nevadan land on the west. (King: 40*th Par.*, i., 731-2, 748.) — First displacements in Rocky Mts. (Stevenson, *Wheeler Rep.*, iii., 499-500.)
5. Between Jurassic and Cretaceous :—Trap mountains and ridges from Nova Scotia to N. Carolina. (D. 417, 486.) — Second movement in the Rocky Mts. (Stevenson, *Wheeler Rep.*, iii., 500.)
6. End of Jurassic :—Sierra Nevada, and Basin Ranges to the east. (D. 452, 486; Whitney: *Geol. Cal.;* King: 40*th Par.*, i., 734-54, 759.) — Blue Mountains, Oreg. (King.) — Humboldt Range. (D. 453, 486.)
7. End of Cretaceous (i. e. in the West, post-Lignitic) :—California west of Sierra Nevada. (D. 523; King: 40*th Par.*, i.) — Wahsatch Range. (King: 40*th Par.*, i., 745, 747, 753. *Not* D. 453, 486; Comstock, *N. W. Wyom.*, 154.) — Part of Rocky Mts. east of Wahsatch. (D. 523; King: 40*th Par.*, i., 748; Stevenson, *Wheeler Rep.*, iii., 500-1.) — Uinta Range. (King: 40*th Par.*, i., 540, 753; Powell: *Uinta Mts.*, 201; Emmons, *King Rep.*, iii., 198-202, 311-6; *not* D. 453, 486.) — Cascade Range. (King.)
8. After Lower Eocene (Vermillion Creek Group) :—Formation of Wahsatch Fault, with subsidence of Central Utah. (King: 40*th Par.*, 745, 755.)
9. After Middle Eocene :—Cherokee Ridge, and plications in Western Nevada. (King: 40*th Par.*, i., 755.) — Pyrenees, Julian Alps. (Murchison: *Siluria*, 499.) — Appenines, Carpathians. (D. 512, 525.) — Southern Himalayas. (D. 512.)
10. End of Eocene :—Perhaps Cordilleras in Wyoming and Utah, and California. (D. 523.) — Subsidence along the East Nevada fault. (King: 40*th Par.*, i., 744, 756.) — Corsican chain. (D. 525.)
11. End of Miocene :—Coast Range, Cal. (D. 523; L. 256, 512; Whitney: *Geol. Cal.*, i., 320, *seq.;* Le Conte, *Am. Jour. Sci.*, iv. 470, vii. 176.) — Rocky Mts. further raised to 11,000 ft. (D. 524.) — Subsidence of "Great Plains" and formation of "Cheyenne Lake." (King: 40*th Par.*, i., 455; Lect. XVI., V. 3, (3).) — Severe crumpling in region of Pah-Ute Lake, and formation of "Sho-

shone Lake," stretching from Sierra Nevada to Wahsatch, and north, far up Columbia R. (King: 40*th Par.*, i., 456.) — San Domingo. (D. 524.) — Western Alps, including Mont Blanc, Monte Rosa, Rigi, etc. (D. 512, 525). — Antrim, Inner Hebrides and Faroe Is. (D. 525.) — Older eruptions of Auvergne and Velay. (D. 525; Ly.: *Man.*, ch. xxxii.; Scrope: *Volcanoes of Central France.*)

12. End of Pliocene:—Tilting of the Great Plains to a maximum of 7,000 ft. — Depression of east and west borders of Great Basin Pliocene, by faulting along eastern Sierra Nevada and western Wahsatch.) King: 40*th Par.*, i., 758.) — Eastern Alps, from Valais to St. Gotthard. (D. 525.)

II. Inductive Inferences.

1. The loftiest mountains developed in later geological ages.
2. The post-Carboniferous, post-Jurassic and post-Cretaceous the principal building times of the modern American continent. (King: 40*th Par.*, i., 759.)
3. Distinction of slow and paroxysmal subsidences. (King, 760.)
4. Distinction of gentle and dislocating elevations. (King, 760-1.)

XXVI. VULCANISM.

On Volcanic Phenomena, see LYELL: *Principles of Geology*, ch. xxiii.-xxvi.; DE LA BECHE: *Geological Observer*, ch. xvii.-xxi.; RÉCLUS: *The Earth*, ch. lxi.-lxxii.; ZURCHER et MARGOLLÉ: *Volcans et Tremblements de Terre*, Paris, 1866; DAUBENEY: *Description of Volcanoes*; NAUMANN: *Geognesie*, i., 76-189; HUMBOLDT: *Aspects of Nature*, Am. ed., 375-99.

On Earthquake Phenomena, see LYELL: *Principles*, ch. xxvii.-xxxii.; DE LA BECHE: *op. cit.*, ch. xxii.; RÉCLUS: *Earth*, ch. lxiii.-lxxviii.; BAKEWELL: *Introduction to Geology*, ch. xix.; ZURCHER et MARGOLLÉ: *op. cit.*, 251-94; NAUMANN: *Geognosie*, 193-286; L. PALMIERI: *The Eruption of Vesuvius in* 1872; R. MALLET: *The Great Neapolitan Earthquake of* 1857, 2 vols., 8vo., 1862. Pt. i.; General Phenomena, Pt. ii., Phenomena of the Neapolitan Earthquake; *Facts and Theory of Earthquakes*, Reports Brit. Assoc., 1850-8.; *On Observation of Earthquake Phenomena*, Admiralty Manual of Scientific Inquiry, 3d ed., 1859. Smithsonian Ann. Rep., 1859, 408-33; *Earthquake-wave Experiments*, Phil. Trans., 1862, vol. cliii.; ALEXIS PERRY, Sundry memoirs on the earthquake and volcanic phenomena of the world, presented to *Academie Royale de Belique*, etc., 1843-1867, and subsequent years in other publications.

On volcanic Rocks, see KING: *Geology of 40th Parallel*, i., ch. vi.; ZIRKEL, in *Geology of 40th Par.*, vi., (for microscopic characters); PUMPELLY, *Geology of Mich.*, 1873, ii., pt. ii., on copper-bearing rocks; HUNT, *Geology of Canada*, 1863, ch. xx., pp. 643-70; RICHTHOFEN: *On a Natural System of Volcanic Rocks*, Mem. Cal. Acad. Sci., 1868, i., pt. ii., 4to.; LYELL: *Manual of Geology*, ch. xxviii., xxix.; DANA: *Man. of Geol.*, 76-9, and *System of Mineralogy*; also general works on Lithology, as cited in Lecture III.

[Theoretical considerations are postponed to Part II.]

Definition and explanation.

I. Volcanoes. (D. 702-16; L. 81; Lyell, Réclus, etc., as above.)

1. General description. (See above.)
2. Locations contiguous to sea-coasts. (D. 703; L. 81-2; Ly.: *Prin.*, 332-40; Réclus, *Earth*, 426-32, map; Hunt: *Chem. and Geol. Essays*, 67-9.) — Rarely far inland. (D. 704.)
3. Volcanic action perpetual or periodical. (D. 714; L. 81.) — Through craters. (D. 711; L. 82.) — Through fissures. (D. 714.)
4. Ejections:—Explosions. (D. 692; L. 82; Ly.: *Prin.*, 445.) — Molten matter. (D. 707; L. 83; Réclus, ch. lxvi.) — Volcanic bombs. (D. 709.) — Ashes and stones. (L. 83; Réclus, 468, 471.) — Mud and water. (Ly.: *Prin.*, 414; Réclus, 475.) — Vapors and gases. (D. 708; L. 85; Réclus, 433.) — Formation of Cone. (D. 704, 710, 715; L. 81, 83, 186-9; Ly.: *Prin.*, ch. xxiv.-xxvii.; *Mannal*, 489.)
5. Particular examples:—(1.) Vesuvius. (D. 714; L. 88; Ly.: *Prin.*, 347-80; Réclus, 448; Zurcher et Margollé, 1-50. — Burial of cities. (L. 83; Ly.: *Prin.*, 369-80; Réclus, 470; Pliny: *Letters:* Zurcher et Margollé, 1-10; Dyer: *Pompeii*, London, 1875, and the works cited, pp. 5-9.)
   (2.) Ætna. (Ly.: *Prin.*, ch. xxvi; Réclus, 419-25; 469: Zurch. et Marg., 51-65.)
   (3.) Kilauea and Mauna Loa. (D. 708-16; Réclus, 430, 460-2; Zurch. et Marg., 200-7; Brigham: *Volcanoes of the Hawaiian Islands*, 1868; Dana, *Am. Jour.*, II., xlvi, 105-23; Coan., *ib.* xlvii., 89; III., ii., 454; III., iv., 406-6.
   (4.) Jorullo. (Ly.: *Prin.*, 411-14; Réclus, 443-4; Zurch. at Marg., 169-76.)
   (5.) Skaptar Jökul. (L. 83; Ly.: *Prin.*, 409-11: Zurcher et Marg., 80-4.)
   (6.) Tomboro. (L. 82, 83; Herschel: *Phys. Geol.*, 111; Ly.: *Prin.*, 45: Réclus, 471; Zurch. et Marg., 192-7.
   (7.) Mt. St. Elias, Shasta. (Whitney: *Geol. Cal.*, i., 332-49.) — Rainier. (L. 81.)
   (8.) Extinct Volcanoes. (D. 525; Newb., *Ives. Col. Explor.*, 65, 72; Ly.: *Man.*, ch. xxx.-xxxii.; Zurch. et. Marg., 225-37, 249.)
6. American Lavas of Post-Pliocene age. (D. 524, 753.) — Immense outflows along the Pacific slope. — Table Mountain. (Whitney: *Geol. Cal.*) — Lithological characters. (King: 40*th Par.*, i., ch. vii., and Zirkel, *ib.*, vi.)
7. Comparison of Lavas of more ancient date. (Ly.: *Man.*, 486-7.)
8. Injections, Intrusions and Outflows:—Veins. (D, 108-14, 731; L. 226; Ly.: *Man.*, 567-72.) — Dikes. (D. 715, 109, 111, 722; L. 87, 207; Ly.: *Prin.*, 363; Ly.: *Man.*, 483; Hayden: *Ann. Rep.*, 1872, 37-9.) — Beds of igneous origin. (D. 717, 185, 418; L. 259; Gilbert, *Wheeler Rep.*, iii., ch. v.; Stevenson, *ib.*, ch. xiv., and p. 501; Loew, *ib.*, ch. xxiii.; Marvine, *Hayden Rep.*, 1873, 129; Peale, *Hayd. Rep.*, 1873, 318-322; Endlich, *ib.*, 345, etc.; Peale, *ib.*, 163-74; Endlich, *Hayd. Rep.*, 1874, 193-209; Peale, *Hayd. Rep.*, 1875, ch. vii.; Endlich, *ib.*, 127-36, 145-8, 212-15; Rhoda, *ib.*, 312; Crittenden, *ib.*, 364, pl. xliv.; Leconte, *Am. Jour.*, Apr., 1874; Comstock, *N. W. Wyom.*, 184.) — Basaltic columns. (D. 716, 722, 86,

87, 421; L. 209-10; Ly.: *Man.*, 483-523; Hayden: *Ann. Rep.*, 1872, 50.) — Metamorphism. (D. 724-31.) — Mountain Forms resulting from lava-outflows. (Powell: *Uinta Mts.*, 18-21; Ly.: *Prin.*, ch. xxiv-xxvii; Ly.: *Man.*, 462, 489-518.)

9. Richthofen's chronological classification. (See General Ref.) — Propylite, Andesite, Trachyte, Rhyolite, Basalt. (King: 40*th Par.*, i., ch. vii.)

II. **Fumaroles or Solfataras.** (D. 718, 708; Ly.: *Prin.*, 347; Réclus, 434, 478, 486-8.) — About volcanic mountains. (D. 708.) — On the coast of the Bay of Naples. — At New Madrid. — New Zealand. (Zurch. et Marg., 208, 321.)

III. **Thermal Waters** (See Lect. II., IV. 2; Réclus, ch. lxx.)

1. Artesian waters. (Lect. II., IV. 4.) — Temperatures.
2. Deep-mine waters. (Lect. II., IV. 3.) — Temperatures.
3. Thermal springs. (D. 719; Lect. II., IV.; Whitney: *Geol. Cal.*, 93-5; Gilbert, *Wheeler Rep.*, iii., 146-55; Hague, *King Rep.*, iii., 704-7, pl. xxi., xxii.)
   (1.) Their common occurrence. — In volcanic and mountainous regions. — Temperatures. (D. 719, 722.)
   (2.) Geysers. (L. 94; Réclus, 482; Zurcher et Marg., 84-94.) — Phenomena. (L. 94.) — Explanation. (D. 721; L. 99-104.)
   (3.) Thermal waters of Yellowstone National Park. (D. 719-21; L. 94-9; Hayden: *Ann. Rep.*, 1871, 162-98; *ib.*, 1872, 52-6; *A. J. S.*, III., iii., 105, 161, maps and views; Peale, *Hayden Rep.*, 1872, 122-158, 173-8; Bradley, *ib.*, 234-50; Jones: *Explor. N. W. Wyom.*, 1873, 24-32; Comstock, *ib.*, 189-259.)
   (*a.*) Especially described and illustrated by Dr. Hayden. (Reports for 1871 and 1872. But see Comstock, *ut supra*, and *Am. Nat.*, Feb. and Mar., 1874; Richardson: *Wonders of the Yellowstone*; Taylor: *Illus. Libr., Trav. and Adventure*, 1873; Doane: *Yellowstone Exped.*, 1870, especially 24-38; also Reports of Superintendents Langford and Norris.)
   (*b.*) Remarkable outbursts, and sintery deposits. (D. 719-21; L. 95-9; Jones: *N. W. Wyom.*, 25-32.)
   (*c.*) Views. (D. 719, 720; L. 95-9; Hayden: *Rep.*, 1871, 66-127; *ib.*, 1872, 54, 122-5; also many photographs in "National Museum," taken by W. H. Jackson.)
   (*d.*) In Colorado. (Peale, *Hayd. Rep.*, 1872, 102-3; Marvine, *Hayd. Rep.*, 1873, 205-6.)
   (*e.*) Thermal Springs of New Zealand. (*Pop. Sci. Monthly*, July, 1879; Réclus, 483; Hayden: *Ann Report.*, 1871, 128; Hochstetter: *New Zeal.*, 452; Zurch. et Marg., 315-20.)

IV. **Seismic phenomena.**

1. Earthquakes. (D. 741, 585; L. 104-26; Ly.: *Prin.*, ch. xxviii.-xxx.; Réclus, ch. lxxiii.-lxxix.) — Destructive occurrences. (L. 120; Ly.: *Prin.*, 441, 447, 471-3, 476, 485; Réclus, ch. lxxv.; Zurch. et Margol., 251, *et seg.*; Hamilton's and Dolomieu's "*Accounts of the Great Calabrian Earthquake.*" Also, South American earthquakes as described by Humboldt, Fitzroy and Darwin; and Javan, by Stamford Raffles; also, Mallet, *ut supra.*)

2. Seismic phenomena in the United States.
   (1.) The New Madrid Earthquake of 1811. (Ly.: *Prin.*, 447-9; *Travels. in U. S.*, 2d vis., ii., 172-82.)
   (2.) Frequent slight shocks of later occurrence. (Twining, *Am. Jour.*, i., 47; Brigham, *Mem. Bos. Soc. N. H.*, ii., i., 227, New England earthquakes; *A. J. S.*, i., 304; J. D. Whitney, *A. J. S.*, III., iv., 316.)
3. Sea-waves. (D. 662; Lect. II., II., 3, (4); L. 119-22; *Rep. U. S. Coast Surv.*, 1855, 1862 and 1869; Ly.: *Prin.*, 478-84; Zurch. et Marg., 268, 281.) — In South America, 1868. (*Am. Jour.*, II., xlvi., 422-8.)
   (1.) Caused by submarine earthquakes.
   (2.) Striking examples:—Lisbon, Simoda, Arica. (D. 662; L. 120.)
   (3.) Measurement of mean depth of ocean. (D. 743; L. 122; *Rep. U. S. Coast Surv.*, 1862 and 1869; Rankine, *Proc. Roy. Inst. Gt. B.*, 26 May, 1871.)
4. Submarine volcanoes and new islands. (D. 711; Ly.: *Prin.*, 415-33; Réclus, ch. lxxi.; Darwin: *Volcanic Islands;* Zurch. et Margol., 327-50; Lect. II.)
5. Slow vertical movements. (Lect. II.; Darwin: *Geol. Observ. on Coral Reefs*, etc., pt. i., 127-46; pt. ii., ch. ii. Also, Humboldt: *Aspects of Nature*, 423—shells 13,790 ft.; Somerville: *Phys. Geog.*, i., 185—shells 17,480 ft.—both cases in the Andes.)

XXVII. EROSIONS.

I. Atmospheric Erosions. (L. 3.)

1. By Winds. — Sand Blast. (D. 632; W. *Grand Traverse Region*, 13; Comstock, Jones' *N. W. Wyoming*, 167-70; W. P. Blake, *Pacif. R. R. Rep.*, v. 108, 230, 232; *A. J. S.*, II., xx., 180; *Proc. A. A. A. S.*, 1855, 218; Newberry, Ives' *Exped.*, 17, 24; G. K. Gilbert, *Proc. A. A. A. S.*, 1874, *B* 26.)
2. By Frost. (L. 8; Comstock, Jones' *N. W. Wyom.*, 19-80.)
3. By Atmospheric disintegration. (L. 6-8; Pumpelly, *Am. Jour.*, xviii., 133; Hayden: *Rep. Montana*, 1871, 34, 39, 43, 61; *Rep. Col.*, 1874, pl. x.; Lyell: *Travels in N. Amer.*, 2d. Visit, ii., 27; Whittaker, *Geol. Mag.*, iv., 447, *etc.*)

II. Aqueous Erosions. (L. ch. ii.)

1. By Rains. (D. 637; L. 9.)
2. By Ice. (See Lectures XVIII. and XIX.)
3. By Waves and Oceanic Currents. (D. 657, 661, 663, 665; L. 31-6; Ag.: *Jour. in Brazil*, 438.) — Receding shores. (D. 663; L. 33; Ly.: *Prin.*, 291-319.) — Rocky islets. (D. 663; L. 35; Ly.: *Prin.*, 287-90.) — Purgatories.
4. By running water. (Ly.: *Prin.*, ch. xiv., xv.) — Continental drainage.

(1.) Producing the great features of continental sculpture. (L. 245-50.)

(2.) Action of moving waters. (D. 638; L. 11, 18-20; Ly.: *Prin.*, 195.) — Corrasion. — Relation to velocity. (L. 18-20; Ly.: *Prin.*, 195. — Force of Alpine torrents. (Réclus: *Earth*, 284-93.)

(3.) Erosions along existing river-valleys. (See Lect. XX.)

(*a.*) Ravines, Gorges, Cañons. (L. 15; Ly.: *Prin.*, 202.)

(*b.*) The Niagara. (L. 12-13; W. 243-5; Hall: Geol. IVth Dist., N. Y.; Ly.: *Prin.*, 203-6; *Travels*, 1st visit; Réclus, *Earth*, 303.)

(*c.*) The Mississippi. (Ly.: *Prin.*, 215; Réclus, *Earth*, 304; Humphreys and Abbot: *Haudraulics of the Miss.*) — Upper waters. — Lower waters. (Ly.: *Prin.*, 211.) — Ancient deeper channel and wider valley.

(*d.*) Kentucky. (W. 344.) — Cumberland, Illinois and others.

(*e.*) Green and Colorado rivers. (D. 640-3; L. Frontisp., 16-7; Newberry, *Ives, Color. Exped.*; W. 345-9; Powell: *Rep. on Col. Riv.*)

(*f.*) The Amazons. (Ag.: *Jour. in Brazil*, 435; Orton: *Andes and Amazon.*)

(4.) Erosion of plateaux, basins and plains.

(*a.*) Colorado plateau. (D. 645; L. 16; W. 346, 348; Ives: *Rep. Col. Exped.*, 63, 76, 80, 98-118; Newb., *Ives' Rep.*, 45, 54-64; Wheeler: *Prelim. Rep.*, 1871, 23; Powell: *Color. Riv.*; Endlich, *Bul. Hayd. Surv.*, iv., 831-64, on erosion in Col.)

(*b.*) Bridger Basin. (King's *Rep. 40th Par.*, iii., 238. — Bear River region. (King's *Rep. 40th Par.*, iii., 326-39.)

(*c.*) Plains of Texas and New Mexico. (Kimball, *Proc. A. A. A. S., Salem*, 174.) — The "Great Plains." — The Basin of Middle Tennesee. (W. 341-3; Safford: *Geol. Tenn.*, 134-5, and map.)

(*d*) Bridges and Arches. (W. 248, 31, 89, 91; Endlich, *Hayd. Rep.*, 1875, 158, pl. xx.; Réclus: *Earth*, 240.)

(*e.*) Circumdenudation. (D. 648.) — Columns, Pyramids, Mesas. (D. 641; L. 16; W. 247; Ly.: *Elem.*, 78, 268, 70, 556; King: *Geol. 40th Par.*, i., 96, Frontispiece, 396-401; Endlich, *Hayd. Ann. Rep.*, 1874, 195, 207; Ives: *Col. Exped.*, 76, 64; Newb., *Ives' Col. Exped.*, 20, 30, 76-91; Endlich, *Hayd. Ann. Rep.*, 1875, 156-8, plates xix., xx.; Holmes, *ib.*, 256, pl. xli., xlii., 268-72, pl. xliv., xlv.; Forsyth, *Yellowstone Exped.*, 1875, 8—"Castle Rocks." — "Garden of the gods." (Peale, *Hayd. Ann. Rep.*, 1872, 100; 1873, 36; Marvine, *Hayd. Ann. Rep.*, 1873, 265; Hayden: *Ann. Rep.*, 1874, pl. viii., ix.) — "Monument Park." (D. 646; Hayden: *Ann. Rep.*, 1873, 32; *ib.*, 1874, 36, 40, and pl. iii., iv.) — Compare needles, columns and tables on glacier surfaces. (Réclus: *Earth*, 193; Tyndall: *Glaciers of the Alps. Hours of Exercise in the Alps*; Lect. XVIII., V.)

(*f.*) "Bad Lands." (L. 247-8; W. 205, 206, 296; Owen: *Geol. Northwest*, 196-9; Hayden: *Rep. Wyom.*, 1870, 145-6; King: *Geol. 40th Par.*, i., Frontisp., 9, 396-401.)

(*g.*) Foreign examples. (Ly.: *Elem.*, 67-78; ch. xix.)

(5.) Erosion of mountains. (See Lecture XXIV., II.)

(6.) Underground erosions. (D. 653-4; L. 68, 70; Réclus: *Earth*, 245-60; Comstock, Jones' *N. W. Wyom.*, 181-2.)

III. **Avalanches, mountain-downfalls and landslips.** (Réclus: *Earth*, ch. xxvii.; Payot: *Guide itinéraire au Mont Blanc;* Bakewell: *Geol.*, 385; Ly.: *Prin.*, 708; D. 655.) — Lowering of Mountains. (Orton, *Am. Jour. Sci.*, ii., 267.)

XXVIII. THE OLD AGE OF CONTINENTS.

I. **The Mass of the Sedimentary Rocks a measure of past denudations.** (L. 263.)
1. Origin of marine sediments.
2. Nearly all the known rocks of sedimentary origin. — Where were the lands worn down to supply the material?
3. Their direction indicated by gradations in the coarseness of the sediments. (D. 373.) — Appalachian materials and their north-eastern origin. (D. 251; Hall: *Pal. N. Y.*, iii., Introduc.) — The Potsdam Sandstone a shale in Alabama.

II. **The Archæan Lands of North America.**
1. Archæan sediments imply shore-erosions.
2. The old Archæan surface extensively eroded *before* Cambrian time. (King: *Geol. 40th Par.*, i.)
3. These lands themselves formerly more extensive. — Eroded *during* Palæozoic time.
4. Their substance built into Palæozoic and later formations.

II. **The old Caribbean Continent.** (Bland, *P. A. P. S.*, xii., 56, *etc.*; Cope, *P. A. N. S.*, 1868; P. T. Cleve, *A. J. S.*, III., iv. 235.)
1. Its surviving relics.
2. Involved small areas in South America.
3. Tradition of a cataclysm in the Antilles. (Foster: *Prehistoric Races, U. S.*, 396-9; Catlin: *The Lifted and Subsided Rocks of America*, Lond., 1870.)

IV. **The Lemurian Continent.**
1. The Mascarene islands. (Milne-Edwards, *Comptes Rendus*, 15 Apr., 1872, 1030-4; *Ann. and Mag. Nat. Hist.*, iv., 72; *Am. Jour. Sci.*, iv., 138.)
2. Evidences of former extension to Java.

V. **A Supposed Polynesian Continent.** (D. 583; Leidy: *Ext. Mam. of Dak. and Neb.*, 1869, 36, 356; Huxley, *Anniversary Add.*, Lond. Geol. Soc., 1870; Cope, *P. A. P. S.*, 1871, 55, 99, and *P. A. N. S.*, 1867, 156.)

VI. **The wasted Aleutian Connection.** (L. 535; W. 25. See under last head.)

VII. **The "fabled" Atlantis.**
1. Historical reminiscences. (Plato: *Timæus* and *Critias*, Jowett's trans., ii., 462, 519-21, 588, 599-607; Theopompus, auc. Aristotle, in Plutarch: *Consolatio ad Apollonium*, § 27; Compare Preller: *Griechische Mythol.*, i., 453; Timagenes, auc. Amm. Marcellinus, in Müller's *Fragmenta Histor. Græc.*, iii., 323; Marcellus, in Müller, *op. cit.*, iv., 443.)

2. The old stump of Atlantis perhaps discovered. (Wild, in *Nature*, March 1, 1877, 377. Compare Thomson: *Voyage of the Challenger. The Atlantic*, i., Ch. ii., App. B., p. 93.) — Grounds for supposing a "Miocene Atlantis." (Heer: *Flora Tertiaria Helvetica*, 1855-9; Saporta, *Annales des Sci. Natur.*, 1862, and *Le Monde des Plantes*, 1878; Newberry, *Hayden's Explor. Yellowstone and Missouri Riv.*, 1859-60, 173-4; Ch. Martins, *Revue des Deux Mondes*, 1867; Cleve, *A. J. S.*, III., iv., 235. See also the palæontological generalizations of Moore, Duncan, Sowerby, Guppy, Leidy, Marsh and Cope.)

VIII. Wastage of visible areas. (D. 637-47, 663-4; L. 245-51; W. ch. xxxi. See also Lectures XXVII. and XXIV.)

1. The Alleghanies. (D. 647; L. 263; W. 339-40.)
2. The Catskills.
3. Faulting and Denudation in Wyoming Territory. (Powell: *Uinta Mts.*; L. 263.)
4. The gold-bearing gulches of California. (L. 554-7.)
5. Sundry other examples. (D. 647; L. 15; E. Hitchcock: *Geol. Vt.*, i., 226; Gilbert: *Geol. of Henry Mts.*)

IX. Rate of Continental Erosion.

1. Croll's estimate, 1 ft. in 6,000 yrs. (*Phil. Mag.*, May, 1868, 378-84; Feb., 1867, p. 1830; *Climate and Time*, ch. xx.; *Trans. Geol. Soc., Glasgow*, iii., 153.)
2. Reade's estimate, 500,000,000 yrs. since sedimentation began in Europe. (*Annual Add., Liverpool Geol. Soc.; Am. Jour.*, 1876, 462.)
3. Geikie's estimate, 1 ft. in 6,000 yrs. (*Proc. Roy. Geogr. Soc.; Pop. Sci. Monthly*, Sep., 1879, 598.)
4. These estimates apparently too low. — Erosion by the Ganges, 1 ft. in 1751 yrs., and by the Mississippi, 1 ft. in 4,640 years. (L. 10-11.)

XXIX. GEOLOGY OF PETROLEUM.

WINCHELL: *Sketches of Creation*, ch. xxv.; Dana: *System of Mineralogy*, 724-5.

I. Chemical Constitution of Crude Petroleum. (Warren: *Mem. Amer. Acad.*, II., ix., x.; *Am. Jour. Sci.*, II., xl., xlv., xlvi.)

1. Series of Hydrocarbons. (D. *Syst. Min.*, 720-2; Crosby, *Am. Nat.*, Apr., 1879, 231.) — Table. — Differential between cellulose and Petroleum. (L. 379.)
2. Compounds more and less volatile. (L. 380; W. 280.)

II. Organic Origin of Petroleum. (L. 379.)

1. Its organic constitution chemically.

2. Its producibility from organic substances and black shales. (D. 268; W. 281.)
3. Its natural association with organic *débris*.
4. The origin chiefly vegetable. — Indications. — The hypothesis of animal origin. (Hunt: *Chem. and Geol. Ess.*, 168-82; *A. J. S.*, III., i., 420-4, on Chicago limestone; *A. J. S.*, ii., 369; *Geol. Canada*, 526-8; A. J. Warner, *A. J. S.*, ii., 215.) — A controversy.

III. Its Vertical Distribution in the rocks. (L. 376-7; W. 280-1.) — In gneiss and mica schist. (*Am. Jour.*, II., xlv., 38.)

IV. Laws of Accumulation. (L. 377; W. 287.)

1. A source situated *below* the place of accumulation.
   (1.) In every actual instance we find a *bituminous shale*. (W. 282, 288; Warner, *A. J. S.*, ii., 215.)
   (2.) Limestones not an abundant source. (W. 277-8; Hunt, *Geol. Can.*, 521-6.)
   (3.) Argillaceous mixtures predispose to liberation of petroleum.
2. An anticlinal axis required to direct the movement of the liberated product.
3. A reservoir to retain the supply. (W. 287.) — Porous sandstone. (W. 293.) — Shattered rock. (W. 292.) — Cavernous limestone. (W. 292.)
4. An impervious covering to prevent escape. (W. 282, 287.)

V. Forms of Inspissated Petroleum. (D. *Man. Min.*, 95; Peckham, *Ann. Jour.*, II., xlviii., 362, and other references there; Hunt, *Geol. Can.*, 521-6.

1. Asphalt. (D. *Syst. Min.*, 751.) — Albertite. (D. 296, 315; Wetherill, Trans., A. P. S., 1852, 353; Hitchcock, *Am. Jour.*, II., xxxix, 267.) Found in Green River Eocene and elsewhere. (Hayden: *Ann. Rep.*, 1870, 144, 181.) — Grahamite. (D. 315: L. 380; Lesley, Proc.. A. P. S., ix., 183; Wurtz, *Am. Jour.*, II., xlii., 420 — Piauzite. (D. *Syst. Min.*, 753.) — Berengelite. (D. *Syst. Min.*, 753.)
2. Pitch-lakes. (On Trinidad, Crosby, *Am. Nat.*, Apr., 1879, 239 *seq.*; Wall, *Proc. Geol. Soc.*, Lond., May 1860.) — "Gum-beds." (W. 291-2: Dana: *Syst. Min.*, 727; Crowther, *Am. Jour.*, II., xlvi., 147, in Mexico.)

VI. Common Fallacies.

1. That Petroleum comes from coal. (W. 276, 280.)
2. That a strong surface show is favorable. (W. 276.)
3. That a saturated rock insures a supply. (W. 277, 278-80.)
4. That geological and hydrostatical principles can be disregarded. (W. 275.) — Formations explored in vain. — Unproductiveness of the Corniferous and Niagara limestones. (D. 222, 256;

W. 278-80, 289-91 ; Hunt : *Chem. and Geol. Essays*, 168-82 ; Warner, *A. J. S.*, ii., 215.) — Surface shows tempting to mislead. (W. 276, 278.)

VII. Formations yielding paying quantities : — Cincinnati Group. (W. 289, 292.) — Hamilton Group. (W, 289, 292.) — Genesee Shale. (W. 288, 293.) — Chemung Group. (W. 293.) — Marshall (Waverly) Group. (W. 293.) — Carboniferous Limestone. (W. 293.) — Parma Conglomerate. (W. 293.) — Coal Measures. (W. 293.) — Cretaceous and Tertiary rocks. (B. S. Lyman, *Trans. Am. P. S.*, xv., 1, Punjab ; *A. J. S.*, III., iii., 392 ; *Report of Colonial Geologists*, London, 1860, 134, seq. ; Schomburgh : *Hist. of Barbadoes*, 553, 569 ; *A. J. S.*, III., iii., 481, Santo Domingo.)

VIII. Phenomena of Oil-Wells. (W. 284.)

1. Pumping wells. (W. 285, 284.) — Spouting wells. (L. 377 ; W. 284.) — Intermittent wells. (W. 285.) — Flowing wells. (W. 285.) — Water wells. — Gas wells. (W. 283 ; Rep. on well in Knox Co., O. ; Wurtz, *Am. Jour.*, II., xlix., 336 ; Newberry, *Am. Chemist*, Dec., 1870 ; *A. J. S.*, i., 146)
2. Productiveness of oil-wells. (W. 286, Appendix, Note VIII.)

IX. Exhaustion and Recuperation of Wells.

XXX. GEOLOGY OF SALT AND GYPSUM.

C. A Goessman : *Chemistry of Common Salt*, Am. Jour. Sci., II., xlix., 78-89.

I. Primordial Origin of the Saltness of the Sea.

1. Early chemical reactions. (W. 59-64 ; Hunt : *Essays*, 2d paper.) — Table. (W. 61.)
2. Why we associate salt and gypsum.

II. Origin of Salt Lakes. (Compare L. 74 ; Darwin : *Geol. Obs.*, pt. ii., 75.)

1. Sometimes solutions of contiguous salt deposits. (W. 295 ; D., 630 ; L. 73.)
2. Generally residua of bodies of sea-water. (L. 73.) — Conditions of their perpetuity. — Shrinkage of most salt lakes. (W. 295 ; L. 75.) — Dead Sea. (Not as in L. 73.) — Great Salt Lake. (D. 561 : L. 75.) — Disappearance of salt lakes. (W. 295 ; Lect. XX., IV., 2.) — By drainage they may become fresh. (D. 23.)

III. Salt Lakes of Former Ages

1. Isolation and evaporation. (W. 297 ; D. 235, 696 ; Hunt : *Essays*, 104.) — Occasional accession of sea-water. (D. 236.) — Mixture of earthy sediments. (D. 235 ; L. 75.)

2. Order of deposition as evaporation proceeds. (W. 297, 302; L. 75.) — The Salina basin. — Same order in artificial evaporation.
3. Why gypsum always accompanies salt — Error of supposing them naturally in separated formations — Gypsum not a secondary product. (W. 297; Compare D. 234, 235; L. 75.)
4. The salt sometimes reduced again to brine. — Salt springs.
5. Thus salt formations proceed from evaporation of ancient outliers of the ocean. (W. 296; D. 235, Compare Réclus: *Earth*, 402, *seq.*)

IV. Conditions of Brine Accumulation.

1. A source located *above*. (W. 300-1.)
2. A dish-shaped conformation. (W. 298.) — Effect of a persistent dip. (W. 298.)
3. Remoteness from outcropping border of the basin. (W. 299.) — Salt springs generally marginal. (W. 299.) — Do not indicate localities where strong supplies may be sought. (W. 299.)
4. A good brine-well must be a pumping, not a flowing, well. (W. 299-300.)

V. Principal Salt-Formations of the eastern United States.

1. The Salina Formation. (W. 303.) — Its distribution. — Source of the supplies in Onondaga county, N. Y. (W. 303.) — Geological structure. (W. 303.) — Affords rock-salt in sundry localities. — Goderich, Ont. (W. 304; D. 234.) — Alpena and Mackinac, Mich. — Hope of reaching it by boring in New York. — Abingdon, Va.
2. The Michigan Salt Group. (W. 304; D. 295, 377.) — Its restriction to Mich. and perhaps Nova Scotia. — Its reservoir the Marshall sandstone. (W. 304.) — Productiveness.
3. The Coal Measures. (W. 305.) — Especially in Mich. (W. 305; *Geol. Mich.*, 165-93.) — The reservoir in the Conglomerate. (W. 305.) — Hence Michigan is underlaid by three concentric salt-basins. — General salinity of Michigan strata, and the cause. — Mineral wells of the state.
4. Other salt and brine deposits in the U. S. — The Cretaceous. (W. 306.) — Petite Anse, La. (W. 306; Hilgard, *Am. Jour.*, Jan. 1869, xlvii., 77; Goessman, *Am. Bur. Mines*, 1867.)
5. European Salt Beds mostly Triassic. (D. 424.)

XXXI. METHOD IN THE HISTORY OF LIFE.

I. The Conception of Progress. (D. 593-7.)

1. Retrospect of organic succession.
2. The progress fluctuating, but real. (D. 598.)

3. Expansion of types mostly upward, but partly downward. (D. 598.)
4. Other possible orders of organic succession.
   (1.) Unchangeability.
   (2.) Regression from primitive perfection.
   (3.) Progress by a succession of unrelated plans (Discontinuous.)

II. Persistence and Pervasiveness of Organic Types.

1. Fundamental Identity in Differentiated structures.
   (1.) Fundamental plans of organic structure. (D. 594.)
   (2.) Exemplification from the Vertebrate type.
      (a.) Generalized conception of the Vertebrate. (Hux., 25; Flower: *Osteol. of Mam.* 104-5; Owen: *The Skeleton and the Teeth*, 26-34.)
      (b.) Homologies of parts. — Limbs. — Jaws.
      (c.) Persistence of the vertebrate conception. — Pervasiveness in diversified modifications.
2. Progressive differentiation of structures fundamentally indentical. (D. 595.) — Progressive cephalization. (D. 596.)
3. The rate of this progress different along different lines of affiliation.
   (1.) Explanation.
   (2.) Hence, different stages of differentiation become contemporaneous.
   (3.) Types representative of earlier times, handed down to later. (D. 594.)
      (a.) The general type of Eozoon existed in all subsequent ages.
      (b.) All forms comparatively lower the representatives of earlier ages.

III. Apparent Breaches of the Law of Progress.

1. Persistent Forms. (Hux.: *Critiques and Addresses*, 186; *Lay Sermons*, 216-27.)
   (1. Globigerinæ. (Hux.: *Lay Serm.*, 198; Carpenter, *A. J. S.*, II, xlix., 415.) — Crinoids. (Sars, *A. J. S.*, II., xlviii., 142; xlix., 130; Lovén, *A. J. S.*, II., xlviii., 429; Pourtales, Bul. Mus. Comp. Zoöl.. Cambr., No. 11; Proc, Roy. Soc., xvii., 168 and Ann. and Mag. Nat. Hist., iii., 383 and iv., 112; W. B. Carpenter, *Phil. Trans.*, 1866, vol., clvi.) — Lingulidæ. (D. 594.) — Discinidæ — *Rhynchonella.* — *Terebratulina caput-serpentis.* (Hux.; *Lay Serm.*, 198.) — *Atrypa reticularis.* — *Strophomena rhomboidalis.* — *Nautilus.* — *Belemnoteuthis.* — *Ceratodus.* (D. 594; Krefft, *Proc. Zool. Soc.*, 1870, 221; Günther, *Ann. Mag. N. H.*, IV., vii., 222; *A. J. S.* III., 387; *Archiv. f. Naturgesch.*, 37 Jahrg., 1871, Bd., i., 321, etc.; Haeckel: *Anthropogenie*, 439, 442, 588, 715.) — *Pleuracanthus.* — Highest Lacertilians.
   (2.) All the (20) classes and 75 out of 92 fossilizable orders have persisted to the present.
2. Regressive Forms.
   (1). Among extinct species.
      (a.) From Cambrian *Paradoxides* to lowest Articulates, and to Molluscs, Radiates and Protozoans (if we ignore Eozoön.)
      (b.) From Cambrian Tetrabranchiates to lower orders of Molluscs and other animals.
      (c.) From Triassic Mammals to Jurassic Dinosaurs and Birds.
   (2.) Among living species.
      (a.) Proteids lower than earliest Amphibians.
      (b.) Pharyngobranchs and Marsipobranchs lower than earliest Fishes.

XXXII. METHOD IN THE HISTORY OF LIFE. (Continued.)

I. The resolution of Organic Types. (D. 597.)

1. Resolution discriminated from Differentiation.
2. Every type the potential or stock of a series of differentiations, and also of resolutions.
3. Unresolved types generally *prophetic*.
   (1.) Sauroid Fishes prophetic of Reptiles.
   (2.) Ornithoscelid Reptiles prophetic of Birds.
   (3.) Ichthyosaurian Reptiles prophetic of Cetaceans.
   (4.) The unresolved Amblypoda prophetic of modern orders of Mammals.
4. Unresolved types often *retrospective*.
   (1.) Labyrinthodonts and amphicœlian Reptiles retrospective toward Fishes.
   (2.) Birds with teeth and vertebrated tails retrospective toward Reptiles.
   (3.) Zeuglodonts and Cetaceans retrospective toward Ichthyosaurs.
5. When a higher differential is unresolved, the type is prophetic; when a lower, it is retrospective.

II. Successive Dominance of Organic Conceptions. (D. 597.)

1. Represented by highly differentiated types which continue unresolved. — As the Reptilian Type of Mesozoic Time. — Hence, it becomes *dominant* by manifestation under many modifications and in many individuals.
2. Examples:
   (1.) Rhizopods in the Eozoic.
   (2.) Nautiloids in the Silurian.
   (3.) Crinoids in the Earlier Carboniferous.
   (4.) Ammonites and Reptiles in the Mesozoic.
   (5.) Mammals in the Tertiary. — Sthenorhines amongst early mammals.
   (6.) Acrogens during the Coal Period.

III. Dominant Types Decline without Disappearing.

1. Foraminifera. — Nautilidæ. — Crinoids. — Terebratulidæ. — Ganoids. — Crocodilians. — Cycads. — Tree Ferns. — Salisburioids, etc.,
2. This results from arrest of differentiation and resolution.

IV. The Progress Ideally Continuous.

1. The same general plans of structure reproduced in successive ages and different orders.
2. This not a demonstration of material continuity.
3. But all the phenomena explicable on the hypothesis of a material or genetic continuity.

XXXIII. UNRESOLVED MAMMALIAN TYPES.

References are abbreviated as explained under Lecture XVII.

Some prominent examples of Unresolved types more particularly considered.

I. No Modern Mammalian Order definitely Isolated in the beginning of Tertiary time. (C. III., 644.)

1. Specifications of primitive ordinal types.
2. Affinities with modern Perissodactyla, Proboscidians, Rodents and Plantigrade Carnivores.

II. Common characteristics of oldest Eocene Mammals.

1. Lack of differentiation among the teeth.
2. The selenodont type of teeth entirely wanting.
3. All the ungulates had upper and lower incisors.
4. These early mammals mostly 5-toed and plantigrade.
5. Brains small and imperfectly convoluted. (Mh. viii., July, 1874.)

III. The type designated AMBLYPODA **by Cope.** (C. VIII., 178, 182, 273, 282.)

1. General characters. — Unites Proboscidea and Perissodactyla.
2. *Coryphodon.* — Connects most generalized Herbivores with most generalized Carnivores. (L. 502.) — Possessing affinities with Perissodactyls, Proboscidians, Carnivores and Dinocerata. (C. VIII., 187.)
3. *Dinoceras.* — Description. — Combined characters suggestive of *Rhinocerus*, Ruminants, Equidæ, *Hippopotamus* and Mastodon.
4. *Uintatherium* (?=*Dinoceras*) united characters of Proboscidians, Tapirs and especially *Dinoceras.* (L. III., 93 seq.)
5. *Orohippus* (?=*Hyracotherium*) has connections with *Palæotherium*, *Palæosyops*, *Anchitherium* and Horse. (C. VIII., 260.)

IV. The type designated BUNOTHERIA **by Cope** (C. VIII., 72, 85,)— has affinities ranging from the gyrencephalous orders to the Prosimiæ, Quadrumana and Carnivora.

1. Creodonts:—Resemble Sarcophagous Marsupials, Dogs, Insectivora, Lemurs, and, in the tibia, *Coryphodon* — Differ from Carnivores in ungrooved upper surface of astragalus, and want of coössification of scaphoid and lunar bones. (C. VIII., 76, 78.) — Differ in certain points from all other orders. (C. VIII., 79.)
2. Mesodonts, intermediate between Creodonts and Lemurs. — Possess affinities with Simiæ, Insectivora and Ungulates.
3. Tillodonts:—*Tillotherium.* (L. 503-4.) — Description — Combined characters of Bear, Rodents, Ungulates (Palæotherium), and Insectivores (Hedgehog.)
4. Tæniodonts:—Inferior incisors like Rodents; upper, suggestive of Edentates; molars, like Tillodonts.

V. The type designated Brontotheridæ by Marsh. (Mh. ix., 245; xi., 335.)

1. *Brontotherium:*—Description, (L. 505.) — Was an odd-toed

Ungulate, but resembled *Dinoceras*, Tapir and Proboscidians. (Mh. xi., 339.)

2. *Menodus=Titanotherium*, related to Tapir, Palæothere, and *Dinoceras*. (D. 506-7.)

VI. **The type of Rhinoceridæ.** (C. ix., 227.) — Presents affinities with *Hyracodon*, *Tapirulus*, Lophiodonts and Tapirs; and indeed with *Palæotherium* and the Brontotheridæ.

VI. **Sundry types.**

1. *Oreodon* united characters of *Anoplotherium*, Deer, Peccary and Camel.
2. *Meniscotherium* united characters of *Palæosyops*, *Hyopotamus* and *Hyracotherium* (? *Orohippus*.) (C. V., 8; VIII., 251.)
3. Eocene *Diplacodon* united characters of *Limnohyus* and Miocene *Brontotherium*. (Mh. ix., 246; xi., 339.)
4. *Hypertragulus* was intermediate between Tragulidæ and typical Ruminants. (C. X., 66.)
5. *Orotherium* united Tapiroids and *Hyracotherium*.
6. *Dinotherium* (Miocene)—earliest of Proboscidioid types, united characters of Elephant, Hippopotamus, Tapir, Dugong and (in marsupial bones) Marsupials. (*Am. Jour.*, II., xxxviii., 427.)
7. Stegosauria possessed affinities with Dinosaurs, Plesiosaurs and remotely with Chelonians. (Mh. *A. J. S.*, III., xiv., 513.)

XXXIV. MISSING LINKS.

I. **Unavoidable Imperfection of the Known Record.**

1. Most animals that have lived have completely perished.
   (1.) The calcareous secretions of marine forms the principal relics preserved.
   (2.) All animals without hard secretions have perished.
   (3.) Terrestrial Vertebrates preserved only by burial in sediments.
   (4.) Fossils of ancient rocks destroyed by metamorphism.
2. The fossiliferous rocks very imperfectly explored.
   (1.) No region or locality completely exhausted.
   (2.) The greater part of the earth quite uninvestigated.
3. The known record presents many gaps in the graduated succession of organic form.
4. But the number and the breadth of the gaps continually diminishing.

II. **Missing Links between Inorganic Matter and the First Known Organisms.** (Dawson: *Story*, 325.)

1. Assuming Eozoön to be organic.
2. Assuming Eozoön to be inorganic.
   (1.) Rank of first Cambrian types, Brachiopods and Trilobites.
   (2.) Absence of Polyzoa. — Appeared in the fifth (Chazy) fauna.
   (3.) Absence of Echinodermata, Cœlenterata and Protozoa.

III. Gap between Invertebrates and Vertebrates.

1. Appearance of Fishes in early Devonian or late Silurian.
2. Rank and distinctness from nearest related older tpyes.
   (1.) Ganoids, Placoderms and Selachians.
   (2.) *Eurypterus* and *Pterygotus*. — May be compared with the later *Pterichthys*. — But no structural resemblance.
3. The gap occupied in the modern world by Myxinoids, (Hux. 109.) Lampreys, (Hux. 110) and Lancelets. (Hux. 104.)

IV. Gap between Fishes and Amphibians and Reptiles.

1. Earliest known Amphibians, *Raniceps*, *Amphibamus*, *Baphetes*, *Anthracosaurus*.
2. Highest type of contemporaneous fishes.
3. This gap also occupied in the modern world by lower Amphibians (Salamanders and Proteids) and Dipnoans. (Hux. 145. Also Lect., XXXI., III., 1. (1).)
4. But reptilian *Eosaurus* also lived with first Amphibians.

V, Gap between Mammals and older Vertebrates.

1. First Mammals insectivorous Marsupials during Triassic. (D. 416.)
2. Not known to be preceded by Birds.
3. The highest Reptiles *followed* the first Mammals.
4. The vertebrate succession is from Lizard-like and Alligator-like Reptiles to Mammals. — No connecting links known, either extinct or living.
5. Or, it is from highest Amphibians (Triassic Labryrinthodonts) to Mammals. — Connecting links equally unknown.
6. But the mammalian line, in the living world, descends two steps lower, in *Ornithorhynchus* and *Echidna*. (Hux. 274.)

VI. No certain connecting links between Marsupial and Placental Mammals.

1. Mammals exclusively Marsupial to end of Mesozoic time.
2. Cænozoic time opens with a diversified fauna of placental mammals.

VII. The Gap between Man and Lower Mammals. (Daws.: *Story*, 328.)

1. The distinction structural, but not in respect to rank of the general structure.
   (1.) Man's organism generally not superior. — In some respects retrospective.
   (2.) But all correlations with his psychic nature a great advance. — Relative capacity of cranium. — Extreme cephalization.
2. No connecting forms as yet discovered. — Not so with existing apes and their predecessors.

VIII. A Gap between Gymnosperms and Angiosperms.

1. To the end of the Jurassic, we know only Conifers and Cycads among flowering plants.

2. With earliest Cretaceous, appear abundant Angiosperms. — These even closely akin to modern species.

XXXV. MISPLACED CONNECTING LINKS.

I. Links structurally intermediate separable into two classes.

1. Intermediate terms chronologically discordant. — Styled by Huxley "intercalary types." (*Critiques and Addreses*, 188.)
2. Intermediate terms chronologically concordant. — Styled by Huxley "linear types." (*Ibid.*)

II. Certain Living Forms intercalary between extinct forms.

1. Gregarinidae stand between *Eozöon* and inorganic matter.
2. Seven Crustacean orders between Cambrian Trilobites and *Eozoön*. — Also all Echinodermata and Cœlenterata.
3. Living Dog-Fishes between Devonian Selachians and lower forms. — Also Hag-Fishes and Lancelets. — Such examples abundant.

III. Certain Extinct Forms intercalary between forms more remotely extinct. (See references, Lecture XV.)

1. *Pterodactylus*, a reptile with wings, ornithic scapula, coracoid and other conformations. (Hux.: 229; Mivart: *Genesis of Species*, 84; Seeley, *Ann. and Mag. Nat. Hist.*, Aug. 1870, 140; *Ornithosauria*, and *Index to Foss. Rem. Woodw. Mus.*) — *Middle Oölite to later Cretaceous.* — *Ornithopsis* Seeley. (*Ann. Mag. N. H.*, IV., v. 279; *A. J. S.*, II., xlix., 393.
2. *Ramphorhynchus* and *Dimorphodon*, reptiles with wings and horny tip of mandibles, but a long tail. (Hux. 231-2.) — *Lower to Middle Oölite.*
3. *Pteranodon*, a reptile with wings, short tail, no teeth, and bird-like head. — *Later Cretaceous.*
4. *Archæopteryx*, a bird, but with long vertebrated tail and separate metacarpals. (D. 447; Mivart: *op. cit.*, 86.) — *Middle Oölite.*
5. *Ichthyornis*, a bird with good wings, but with socketed teeth and bi-concave vertebræ. — *Later Cretaceous.*
6. *Hesperornis*, a bird with poor wings, and teeth in grooves. — *Later Cretaceous.*
7. Typical aquatic and cursorial birds. — *Later Cretaceous.*
8. Remarkable showing of the preceding list of forms.
   (1.) A striking general graduation from reptile to bird.
   (2.) A strange crossing of structural affinities.
   (3.) The line runs toward "carinate" and not "struthious" birds.
   (4.) But the chronological order is not conformable to the structural.

IV. Another structural passage between Reptiles and Birds. (Hux., 225-6; C.I., 86-90. See also references, Lect. XV.) — Gen-

eral characters of the Ornithoscelids. — Generally regarded as showing transition toward Struthious Birds. (C. I., 86-90.)

1. *Iguanodon*, a reptile having tips of premaxillaries toothless. — *Older Cretaceous* or *Later Jurassic.*
2. *Rhynchosaurus*, with toothless mandibles. — *Trias* of Europe and America.
3. *Hadrosaurus* and *Lælaps*, with weak fore-legs and probably bipedal attitude. — *Cretaceous* of America.
4. *Anomœpus*, with four toes before, and three bird-like toes behind. — *Trias* of Connecticut valley.
5. *Compsognathus*, with light, bird-like head, and astragalus anchylosed to tibia. (Hux., 225, 228.) — *Middle Oölite.*
6. *Laosaurus* and *Hypsilophodon*, resembling last, but having ornithic ischiac and post-pubic bones, and three toes. (Mh., xvi., 415-6, pl. viii-x.)
7. *Brontozoüm*, bipedal, three-toed, with ornithic arrangement of phalanges. — *Trias* of Connecticut.
8. Typical Struthious Birds. — *Later Cretaceous.*
9. Conclusions from this showing:—The structural gradations real. — They run toward Struthious, and not Carinate, Birds. — The most bird-like Ornithoscelids the oldest. —. Types connecting them with other reptiles *follow* instead of preceding. — The bulk of the reptile-fauna lived *after* the most bird-like genera. — Real birds believed to have existed simultaneously with the most bird-like reptiles. — Mammals certainly lived at the same time. — Nevertheless, the idea of *serial relations of structure* was extant in the world.

V. Inferences from misplaced links only provisional.

1. Not at liberty to infer that the real chronological order was not conformable to the structural.
2. Future discoveries may bring many of the facts into chronological adjustment.

XXXVI. CONNECTING LINKS CHRONOLOGICALLY ADJUSTED.

Besides the works cited below, see Albert Gaudry, in researches on the fossils of Pikermi and Mont Léberon; W. Kowalewsky, in investigations of the osteology of Hyopotamidæ; Huxley: *Critiques and Addresses*, 181-217, Ann. Add., 1870; New York Lectures, 1876, N. Y. Tribune Extra, No. 36; Cope: *Stratigraphic relations of the Orders of Reptilia*, in Proc. Am. Acad., Boston, xix., 194; Am. J. S., III., ii., 217. Consult, also, Haeckel: *Natürliche Schöpfungsgeschichte* and *Anthropogenie* (both in English translation. See further, Part II., of the Syllabus.)

I. **The Horse-Series.** (See Lect. XVII., IV., 1, (4) (*b*).)

1. *Equus* of the living fauna. (Hux. 293-307.) — Marked state of structural isolation.
   (1.) Structures of the fore-limb.
   (2.) Structures of the hind-limb.
   (3.) Structures of the teeth.
   (4.) Five or six American species, beginning late in Pliocene.
2. *Pliohippus*, of middle Pliocene or earlier. — Smaller size. — Central digital series more slender. — Splints more elongated. — Crown of Upper molars shorter, and crescentic areas simpler.
3. *Protohippus*, of Early Pliocene. — Size of Ass. — Central digital series still more slender. — Splints terminated by dangling hooflets. — Ulna long as arm, but slender. — Fibula rudimentary. — Crowns of molars much shorter. — *Anchippus* and European *Hipparion* (= *Hippotherium*) were closely related, and *Merychius* was probably identical. — *Anchippus*, *Hipparion* and *Stylonus* constitute a collateral series. (Cope, IX., 14.)
4. *Miohippus*, of Late Miocene of Oregon. — Size of sheep. — Three functional toes before and three behind. — Also small splint of Vth digit, before. — Ulna distinct, long as radius, but very slender distally. — Fibula co-ossified with tibia at lower end. — Molar crowns decidedly short. — Enamel folds much simpler than in horse. — The Older Miocene *Anchitherium*, the oldest equine known in Europe, is closely related, but a little more specialized.
5. *Mesohippus*, of Oldest Miocene. — Size of sheep. — Three functional toes before and three behind, but more nearly equal than in *Miohippus*. — Larger splints of Vth digit, before. — Radius and ulna distinct, and also tibia and fibula.
6. *Epihippus*, of Later Eocene. (Mh. *A. J. S.* III., xvii., 504.) — Resembled *Orohippus* in its digits, but differed in its teeth.
7. *Orohippus* of Middle Eocene of Wyoming and Utah. — Size of fox. — Four functional toes before and three behind. — Ulna complete and distinct from radius; tibia and fibula also distinct. — Molar crowns exceedingly short. — Enamel pattern simple.
8. *Eohippus*, of Oldest Eocene of New Mexico. — Size of fox. — Four functional toes before and three behind. — Rudiment of outer or Vth toe behind, and hence, probably of Ist digit before. — Hoofs mere thick, broad and blunt claws. — Molars less specialized than in *Orohippus*, without cement. —

Other structures similar. — Carpal bones eight, and somewhat similar to tapir.

II. The Camel Series. (See Lecture XVII, V, 1, (2), (e) and VI., 1, (1).

1. *Camelus* of the living fauna. (Hux. 329.) — Cervical vertebræ. — Metacarpals *separated only by deep cleft.* — Large canines in each jaw. — Premaxillaries each with *one incisor.*
2. *Procamelus* (=*Homocamelus*) of the Pliocene of Colorado. — Premaxillaries with full set of incisors; but *the lateral temporary.* — External incisors and canines alike. — Molars 4–3. — Lateral rudimentary metacarpals wanting. — Trapezoides wanting. — Middle metacarpals *finally united.*
3. *Protolabis* of the Pliocene of Colorado. (Cope, *P. A. N. S.*, 1876, 145; VIII., 325.) — *Full set of permanent upper incisors.* — Molars 4–3, but the posterior are sub-prismatic.
4. *Poëbrotherium* of the Miocene of Colorado. — Molars 4–3, as in primitive mammals generally. — The two metacarpals *distinct.* — Rudiments of lateral metacarpals. — The presence of a trapezium, two digits and separated metacarpals allies it with the older Anoplotheridæ.

III. The Rhinocerus Series. (C. XI., 227-33.)

1. *Cœlodonta* of the Pliocence had dentition $i\ \frac{0}{0\text{-}1}$, $c\ \frac{0}{0}$, and three anterior digits.
2. *Atelodus* of the Upper Miocene had the same.
3. *Ceratorhinus* of the Middle Miocene had $i\ \frac{1}{1}$, $c\ \frac{0}{1}$, and digits the same. — *Rhinocerus* of the Upper Miocene and recent fauna had the same.
4. *Aceratherium* of the Lower Miocene, had $i\ \frac{2}{1}$, $c\ \frac{0}{1}$, and *four* anterior digits, and no horn. — *Zalabis* of the Upper Miocene had $i\ \frac{3}{2}$, $c\ \frac{0}{1}$; but this genus, as known, was chronologically misplaced.
5. Other characters of the genera were correspondingly graduated.

IV. Sundry Examples. (See further, Huxley: *Critiques and Addresses*, 188-90; Owen: *Anat. of Vertebrates*, ch., xl., § 424; Cope, *Proc. Am. Acad.*, xix.)

1. *Dicrocerus* stands between *Antilocapra* and other mammals.
2. *Blastomeryx*, between *Cariacus* and older forms. (C. VIII., 223.)
3. Miocene *Hyracodon*, between Eocene *Hyrachyus* and modern mammals. (Mh. ix., 244.)
4. *Cercoleptes*, between Carnivora and Quadrumana.

5. *Diplacodon*, between *Limnohyus* and *Brontotherium*. (Mh. ix., 246.)
6. Pliocene *Squalodon*, between living Cetacea and Eocene *Zeuglodon*. (Hux.: *Crit.*, 190.)
7. The elephant series extends back through *Elephas*, Miocene *Dinotherium*, Eocene *Dinoceras*, Lower Eocene *Coryphodon* to ?*Oligotomus*. (C. III., 648.)
8. *Dinotherium* possessed Marsupial bones.
9. The oldest Tortoises (*Psephoderma*) intermediate between Lacertilia and typical Tortoises. (Cope, *Proc. Am. Acad.*, xix., 194.)

XXXVII. MAN IN THE LIGHT OF GEOLOGY.

I. Man the Fulfillment of the Prophecies of the Ages.

1. Meaning of the announcemont of a Law of Progress.
   (1.) Progressive improvement of organic types.
   (2.) Prophecy of the earliest Vetebrate. — Man in potentiality.
   (3.) Progressive modification of limbs.
      (*a.*) Fish. — Amphibian. — Reptile, — Bird. — Mammal.
      (*b.*) Proclamation that man must conform to the same plan.
      (*c.*) Psychic relations superadded to structural in the human arm.
2. Promise of an intelligent being in geological adaptations having relations only to man. — Coal. — Metals. — Wells and Springs.

II. Man's Birth-place Foreshadowed.

1. Faunal characteristics of the existing continents.
2. These established before the advent of Man.
3. The pinnacle of organization fixed in the Orient.
4. Corroborative evidences of Man's oriental origin.
   (1.) Human migrations, as far as known, have been eastward. (*Am. Jour.*, II. xlv., 376; Max Müller: *Chips*; *Atlantic Monthly*, 1878; T. Poesche: *Die Arier*. erstes Buch.; Jubainville; *Les prem. Habitants de l'Europe*, ch. iii., iv.) and westward from the Orient. (Jubainville: *ut sup.*, and generality of writers.)
   (2.) Cultivated plants have come from the East. (*Pat. Office Rep.*, 1859, 299, 361) — Of 770 plants used for food, 565 came from the Eastern hemisphere. — Of 237 amylaceous plants, 191 originated in the Old World.

III. Man the Culmination of the Organic Series.

1. The erect attitude attained. — Progressive elevation of the longitudinal axis in older vertebrates.
2. Man a cosmopolite, in opposition to the law of increasing restriction of geographical range.
3. Nature, in man, seems to have reached a period.
   (1.) Other animals his equal or superior structurally.
   (2.) Man's structure, in some respects, retrospective.
   (3.) In cephalization, far in advance.
4. Spiritual (educational) progress still possible.
5. Functional limitation of the progress of spiritualization.

IV. Man's Advent since the Last Great Geological Revolution.

1. Restriction of human relics to most superficial deposits.
2. Man of history not preglacial.
3. Man of historical regions not preglacial.
4. Geological evidence knows nothing inductively, as yet, concerning man of unhistorical races and regions.

V. Geological Man, as far as known, the Equal of Existing Races.

VI. Links Missing between Man and the animals next lower. (Lecture XXXIV, VII.)

1. Man's affinities with anthropoid apes and lower Quadrumama.
2. Not held by evolutionists as a descendent of these.
3. No known relics of his assumed line of descent.
2. Provisional inferences of Wallace as an evolutionist.
5. Consequences of the establishment of Man's derivating origin.

VII. Man's Organism bound up with the history of the Material World.

2. Identified with its inorganic history. — Always conditioned by physical surroundings.
2. Identified with its organic history. — Interwoven in every plan of organic structure and function.

VIII. Indications of a Psychic Principle correlated to the Immaterial and the Immutable.

1. The plans of nature the products of Intelligence.
2. Forms change and perish, but nature's conceptions endure.
3. Man comprehends nature, and thus thinks the thoughts of the Author of nature.
4. That which thinks as the Author of the Universe thinks, possesses a kindred nature, spiritual and imperishable.

PART II.

THEORETICAL GEOLOGY.

XXXVIII. INTERNAL CONDITION OF THE EARTH.

[The questions concerning the internal condition of the earth, metamorphism and the dynamics of volcanoes, earthquakes and mountain-making are so intimately connected that most of the works cited here, and in Lectures XXIV, XXVI and XLIV, may be advantageously consulted on each of these subjects.]

W. HOPKINS, *Transactions Royal Soc.*, 1836, p. 382; 1839, p. 38; 1840, p. 193; 1842, p. 48, maintaining existence of a very thick and completely solid crust; *On the Geological Theories of Elevation and Earthquakes*, Report Brit. Assoc. 1847, pp. 33-93, assigning vapors as a cause; Q. J. Geol. Soc., viii, 56.

HENNESEY: *Researches in Terrestrial Physics*, Phil. Trans., 1851, 545.

POULETT SCROPE: *Volcanoes*, 8vo., 2d ed., 1872; *Geol. Mag.*, Dec. 1878.

KEFERSTEIN: *Naturgeschite des Erdkorpers* 1834, vol i, 109; *Bull. Soc. geologique de France*, I. viii, 197.

CHARLES BABBAGE, *Geological Notices*, No. 36; *Proc. Geol. Soc.*, Lond., 1836 ii; *Ninth Bridgewater Treatise*, Note G, 209-220.

SIR JOHN HERSCHEL, *Proc. Geol. Soc.*, Lond., 1836, ii, 548; Babbage's *Ninth Bridgewater Treatise*, Note I, 225-247.

ROBERT MALLET, *Dynamics of Earthquakes*, Trans, Roy. Irish Acad., xxi, pt. i, 1846; *First Report* to the Brit. Assoc., 1850; *Facts and Theory of Earthquakes*, Trans. Brit. Assoc., 1857-8., Fourth Report, (Other Reports in 1851, 1852, 1853, 1854); *The Great Neapolitan Earthquake of* 1857, 2 vols., 8vo, 1862, pt. iii, Principles of Seismology; *Earthquake Wave Experiments*, Phil. Trans., 1862, vol. cliii; *Note on the History of certain recent Views on Dynamical Geology*, A. J. S. III v. 302, Apr. 1873; *Volcanic Energy: An Attempt to develop its true Origin and Cosmical Relations*, Phil. Trans., 1873, pt. i, 147, abstract, A. J. S., III, iv, 409-12, vii, 145-8; *Additions* to the foregoing memoir, Phil. Trans., 1875, vol. clxv, pt. i, (read May, 1878), abstract, A. J. S., III, viii, 140-1; *On the present state of knowledge of Terrestrial Vulcanicity, the Cosmical Nature and Relations of Volcanoes and Earthquakes*, an Introduction to Prof. L. PALMIERI's work on the *Eruption of Vesuvius in* 1872, extract, A. J. S., III, v. 219-25; *On the Mechanism of Stromboli*, Trans. Roy. Soc., 25 June, 1874, abstract, A. J. S., III, viii, 200-2; *On the Temperature attainable by Rock-crushing, and its Consequences*, Phil. Mag., July 1875 and A. J. S., III, x, 256-68; On the Origin and Mechanism of Production of Prismatic or Columnar Structure of Basalt, Proc. Roy. Soc., 21 Jan. 1875, abstract A. J. S., III, ix, 206-11.

T. S. HUNT: *Chemical and Geological Essays*, (see also, review of same by J. D. Dana, A. J. S., III, ix, 102-9), especially *Theory of Igneous Rocks and Volcanoes* (1858), pp. 1-10; *Probable Seat of Volcanic Action*, (1869), pp. 59-69; *Criticism* of Joseph Leconte's views, A. J. S., III, v. 264-70 (1875).

SIR W. THOMSON, *Phil. Trans.* May 16 and Nov. 27, 1862, xii, 103, *ib.*, 1864, on necessary rigidity of the earth; Thomson and Tait's *Natural Philosophy*. §§ 832, 833, 834, 847, 848; *Trans. Geol. Soc.*, Glasgow, iii; *Trans. Roy. Soc. Edinb.*, xxiii, pt. i, 157, on the secular cooling of the earth; *Nature*, Jan. 18 and Feb. 1, 1872, objections to Mallet's theory.

J. D. DANA, A. J. S., II, v, 423; vi, 6-14, 104-6, 161-72. (See references Lect. XLIV). Also A. J. S., II, ii, 385; iii, 94, 176, 380; iv, 88; xxii, 305, 335.

E. W. HILGARD: *On some points in Mallet's Theory of Vulcanicity*, A. J. S., III, vii, 535-46, June, 1874, and Phil. Mag., July, 1874, 41.

J. D. WHITNEY: *North American Review*, Apr. 1869.

HENRY WURTZ: *Amer. Jour. of Mining*, 25 Jan. 1868; A. J. S., III, v. 385.

DAUBRÉE: *Synthetical Studies and Experiments on Metamorphism, and on the Formation of Crystalline Rocks*, Ann. Report of the Smithsonian Institution, 1861, 228-314 trans. from *Annales des Mines*, 5 ser., xvi, 155, 393, many references appended. On *theory* see pt. iii.

O. FISHER, *Remarks upon Mr. Mallet's Theory of Volcanic Energy*, Q. J. Geol. Soc., Lond., xxxi, 469-78, 12 May, 1875; *Camb. Phil. Trans.*, xi, pt. 3, p. 489; *ib.* pt. 2, p. 18.

GEN. G. J. BARNARD, Smithsonian Contributions, No. 240, difficulties in Mallet's theory, but surmountable.

DELAUNAY, *Comptes Rendus*, July 13, 1868; *Cours elementaire d'Astronomie*, 643, 644.

STANISLAS MEUNIER: *Le Ciel Geologique*, 1871, 223.

D. FORBES, *Nature*, 6 Feb. 1872, difficulties of Mallet's theory.

F. W. HUTTON, *Nature*, 27 Nov. 1873, difficulties of Mallet's theory.

N. S. SHALER, *Proc. Bos. Soc. Nat. Hist.*, x, 237; xi, 8; *Geol. Mag.*, Nov. 1868, v. 5, 11; Atlantic Monthly.

ARCHDEACON PRATT, *Phil. Mag.*, xli, 307, 1871.

See, also, JAMES HUTTON: *Theory of the Earth, with Proofs and Illustrations.* In 4 pts. Edinb. 2 vols. 8vo., 1795; JOHN PLAYFAIR: *Illustrations of the Huttonian Theory of the Earth*, Edinb., 1802; YOUNG: *Lectures on Natural Philosophy*, i, 717, 1807; GAY-LUSSAC: *Annales de Chemie*, xxii, 428; MILNE: The Lisbon Earthquakes of 1875 and 1861, *Edinb. Phil. Jour.*, xxxi; POISSONS: *Note sur le rapport qui existe entre les refroidissements progressif de la masse du globe terrestre et celui de la surface*, Comptes Rendus, xix. 1844, and l'Institut, 1845, 32; B. TRASK, On California Earthquake of Jan. 1857, A. J. S., II, xxv, 146; J. SCHMIDT: *Das Erdbeben von 29 Juli*, 1846; and *Untersuchungen über dem Erdbeben am 15 Jan.* 1858.

I. Indications of Internal Heat. (Lects. II. and XXVI.; D. 699.)

1. Traces of former heat upon the earth's surface.
2. Deep excavations, thermal waters, volcanoes.
3. Hypothesis of intense chemical action. (Sir H. Davy, *Phil. Trans.* 1828, 1832; Lyell: *Prin.*, 527-32; Daubeney, *Jameson's Edinb. New Phil. Jour.*, liii., and *Encyc. Metrop.* pt. 40; Ennis: *Origin of the Stars.*
4. More probable inference of a long cooling process still continued.

II. Hypothesis of thin Crust and Molten or Pasty Interior. (O. Fisher, *Camb. Phil. Trans*, xii. pt. ii.; Descartes: *Principes de la Philos.*, 1644, pt. iv., §§ 2, 44, 72; Newton; *Principia Math. Phil. Nat.*, 1667; Leibnitz, *Acta Eruditorum*, Jan., 1693, and *Protogæa*, 1749; Buffon: *Les epoques de la nature*, 1778.)

1. Solidifying substances float in the molten magma. — Water, type-metal. — Solidifying iron (*College Courant*, 13 Apr. 1872, p 173; *Nature*, 10 May, 1877, 23; 8 Aug., 1878, 397, conclusive experiments; 29 Aug., 1878, 464; xvi., 23; Mallet's apparently contradictory experiments, *Nature*, No. 156, abstr. A. J. S., III., viii., 212; A. Schmidt, A. J. S., III., viii., 287, explaining Mallet.) — Lava floating on liquid lava. (Scrope: *Volcanoes*, 84; Kaemtz: *Meteorology*, 152; Marsh: *Man and Nature*, 545.

2. Cooled terrestrial materials would float.
3. Indications of such a constitution of the earth.
   (1.) Observed rate of increase of downward temperature. (Lects. II. and XXVI.)
   (2.) Enormous lava outflows in geologic and recent periods. (Lect. XXVI., I.)
   (3.) Reputed influence of moon on earthquakes. (Lect. XXVI., IV., 1.)
4. Objected, that such a constitution gives the earth too little rigidity. (W. Hopkins, Thomson, *ut sup.*, and Barnard's reply.)

III. Hypothesis of a Solidified Interior. (W. Hopkins, W. Thomson.)

1. Enormous pressure upon the central portions of the earth. — Solidification the probable result. — This preceding superficial solidification, (Thomson)
2. General admission of this hypothesis.

IV. The Sources of Lava Supplies.

1. Theory of a *plastic zone* between the two solidified portions, (Hunt, as above.)
   (1.) A transitional zone must probably exist. — Too hot to be congealed, and too superficial to be pressed solid.
   (2.) Zone not supposed continuous. — Contiguous volcanoes, like Mauna Loa and Kilauea, not always sympathetic, (*N. A. Review*, cviii., 598.) — Refrigeration may, in some places, reach the depth of solidification by pressure. — Hypothesis of lakes of plastic matter.
   (3.) Position and volume of the plastic zone changeable, as pressure or conductivity of overlying masses varies.
2. Theory of a semi-fluid interior combined with superheated water, (Fisher, Camb. Phil. Trans, xii., pt. ii.) — Assumes a combination not known to be possible.
3. Theory of melting heat as the result of lateral crushing pressure (Wurtz, Mallet, Leconte, Hilgard.)
   (1.) Terrestrial shrinkage from cooling.
   (2.) Experiments on the development of heat by crushing, (Mallet.)
   (3.) Objections made to the contractional theory, (Thomson, Fisher, Barnard, Hutton, Dutton.)

V. Denials of any Knowledge of the Earth's Interior. (Evan Hopkins; James Hall, *American Institute Lecture*, New York, 1869, cited in W. 434.

XXXIX. PRIMORDIAL HISTORY OF THE EARTH.

LEIBNITZ: *Protogæa*, 1749, (abstract in *Acta Eruditorum*, Leipzic, 1683.) or synopsis of this by CONYBEARE, in Report British Association, 1832; BUFFON: *Theorie de la Terre*, 1849; *Epoques de la Nature*, 1775.

I. All Presedimentary History Reached only by Deduction.

1. The oldest known rocks sedimentary. (Lect. III.)

2. But a process of cooling implies a fire-formed crust. — This probably remelted by ascent of geisothermal planes. (Lect. III., I., 3.)
3. May reason backward, on the basis of the laws of matter and force. — This brings us to a completely molten condition. (D., 146; W., 28–35; Leibnitz, *ut supra.*) — Then to a vaporous one. (D., 146; W., 36–9.)
4. The fluent condition indicated by the earth's spherical form.
5. A shrinkage explanation must probably be given of the counteraction of the retarding influence of the tides on the earth's rotation during 2,000 years. (W., 403–5; Helmholtz: *Interac. Nat. Forces*, Youmans' ed., 243–7; Mayer: *The Tidal Wave*, Youm., ed., 299, and *The Earth's Internal Heat*, 312.)

II. The Volatility of all Matter.

1. The solid, liquid and gaseous conditions dependent chiefly on Temperature and Pressure. (Lyell: *Prin.*, 538.) — Familiar examples. — Volatilization of silica in the Bessimer process of steel-making. — Volatilization of iron by Dr. Elsner. — Condensation of carbonic acid by Dr. Hare. — Condensation of nitrogen, hydrogen and other gases by Pictet and Cailletet.
2. Distinction between the gaseous and the vaporous states.
   (1.) The *gaseous* a state of dry molecularization or of atomization.
   (2.) *Vapor* or *mist* consists of minute spheres of liquid matter in suspension either in a fluid or removed from the considerable action of gravity.
   (3.) Minute particles of solid matter in similar suspension form *dust.*
3. Rational to assume terrestrial cooling to have proceeded from a state of vapor, or even of gas. — Enormous volume of the planet in this condition. — This assumption sustained by our knowledge of other cosmical vapors, as sun, stars and nebulæ.

III. Passage from fire-mist to a molten globe.

1. Rain of molten matter. — Growth of the liquid core. — An incandescent liquid globe. — Central solidification by pressure.
2. A fervid and heterogeneous atmosphere. — Many substances still gaseous. — Struggling sunbeams.
3. Rolling tides of lava.

IV. Freezing of the Molten Sea. (Comp. Lect. XXXV I., II. I.)

1. Crystallization of the most refractory substances. Crystals of augite, leucite, mica and black garnet erupt in great abundance in semi-fluid lava from Vesuvius. — Formation of first solid film. — Its composition. — Its incessant ruptures and recementation. — A lava floe. — Continents established. — A crust glowing with heat.

2. Later probable ruptures and repairs. — The cause and consequences.

V. Appearance of Water, (W. 52-5.)

1. The temperature hitherto too high for its existence.
2. Gathering clouds. — Sun-light veiled out. — The still self-luminous earth. — All substances red-hot at about 977° Fah. (J. W. Draper, *A. J. S.*, Jan. 1877, 67).
3. Descending rains. — Electrical disturbances. — The war of fire and water. — The stormy period.

VI. Ascendancy of the Waters.

1. A universal ocean film. — Acid rains. — Attacks upon the rocks. — The war of chemical affinities. (W. 56–64; Hunt: *Chem. and Geol. Essays*).
2. Beginning of sedimentation. (Lect. VI.) — Chemical and mechanical deposits.
3. An age of physical violence. — Ruptures of the ocean's floor. — Explosive generation of steam. — Tepid waters and reeking skies.
4. Probable advent of marine plants. (Lect. IV., I.)

VII. Germs of Continents appearing above the waves.

1. The first mechanical sediments must have proceeded from the fire-formed crust.
2. Mechanical erosion effective only along a shore-line.
3. There must, consequently, have been a shore-line on a fire-formed land. — Such lands the germs of future continents. (Lects. XXIII, XXIV, XLIV.)

XL. NEBULAR THEORY OF WORLD—GENESIS.

EMANUEL KANT: *Allgemeine Naturgeschichte und Theorie des Himmels, oder Versuch von der Verfassung und dem Mechanischen Ursprunge des ganzen Weltgebundes, nach Newtonschen Grundsatzen abgehandelt.* Königsberg u., Leipzig, 1755. Kant's sämmtliche Werke Bd. i., S. 207.

DR. LAMBERT: *Lettres Cosmologiques*, 1761; *Cosmological Letters*, 1828.

JOHANN ELERT BODE: *Anleitung zur Kentniss des gestirnten Himmels, circa*, 1767.

PIERRE SIMON, Marquis de LAPLACE: *Exposition du Systeme du Monde*, Paris, 1796, tome ii., ch. 6. See translation in ENNIS: *The Origin of the Stars.* Appendix V.

Compare also A. WINCHELL: *Sketches of Creation*, ch. iv.; *Unity of the Physical World*, Meth. Quar. Rev., Jan., 1874; *Geology of the Stars*, 1873; FIQUIER: *The World before the Deluge*, 16-29; ENNIS: *The Origin of the Stars;* MILL: *System of Logic.* Bk. ii., ch. xiv.; L. SAEMANN: *On the Unity of Geological Phenomena in the Solar System*, Bull. de la Soc. géol. de France, 4 Feb., 1861, and Canadian Naturallst, vi., 444-51; SAIGEY: *The Unity of Natural Phenomena*, transl. 12 mo., 254 pp., Boston, 1873.

I. Common conditions pervading the Solar System.

1. Common motions. — Orbital, axial, eastward, elliptic, zodiacal. — Kepler's three laws.
2. Common forms.
3. Common substance. — Spectroscopic revelations. — Meteoric matter.
4. Laws of light. — Etherial medium. — Gravitation.
5. The bodies of the system (not including comets) must have had a common history.

II. A common primitive Fire-mist.

1. The whole solar system an ancient sphere of incandescent vapor. — Its physical constitution.
2. Probably an older condition and another form of matter. — Analogical inference of heated, non-luminous, aëriform matter.
3. Cosmical analogies of the fire-mist.
   (1) The solar photosphere. (Proctor: *The Sun;* Secchi: *Le Soleil*). — The solar nucleus perhaps a non-luminous, intensely-heated gas. (Faye: *Comptes Rendus*). — Its constituents in a state of molecular dissociation.
   (2) The fixed stars possess a similar constitution.
   (3) The nebulæ still more striking examples.
   (4) The condition of illuminated dust probably seen in the rings of Saturn and in comets and the Zodiacal light.

III. Behavior of a Sphere of Fire-mist in space.

1. It would radiate heat.
2. Through cooling it would shrink.
3. If not rotating, a rotation would be established.
   (1.) By the impinging of exterior masses against it. (Lect. XLIII.)
   (2.) By distortion of form and change of position of centre of gravity through external attractions. — Descending portions would thus pass one side of the centre of gravity and generate tangential forces.
   (3.) By the establishment of superficial currents in passing from an amorphous to a spherical form.
4. Rotation would be accelerated with shortening of diameter. — Velocity inversely as the square of the equatorial diameter.
5. The mass would become an increasingly oblate spheroid.
6. The equatorial periphery would at length become equilibrated between centripetal and centrifugal forces.
7. It would no longer descend toward the centre, and the portion within would shrink away from it, leaving a rotating ring.
8. Other rings, in succession, would be similarly detached.

IV. Behavior of a Ring of fire-mist surrounding a sphere.

1. It would continue to rotate approximately in the plane of the sphere's equator. — But its equilibrium would be unstable.

2. It might assume a stratified condition and resolve itself into a system of concentric rings. — Influence of different velocities of rotation of outer and inner parts. — And of different densities in the substance.
3. External attractions would disturb the symmetry of its movements.
   (1) A "wobbling" motion might ensue. — This would be continually exaggerated until the ring or rings should be broken.
   (2) The centre of gravity of the ring might be drawn to one side of the centre of figure. — The matter would tend to flow to the side nearest this. — The opposite side would become progressively more tenuous.
4. However broken, the ring would gather itself spherically about one center. — This sphere would travel orbitally in the path determined by the position of the ring. — The orbit at first circular and unstable, would, through perturbations, become elliptic and stable. — The sphere would rotate axially in the same direction. (Ennis: *Origin of the Stars*, Sec. XXX). — Thus the matter of a planet would become isolated. — All the planets in succession would assume their places.
5. A stratified ring or system of rings might form a zone of planetoids.

V. Behavior of a Planetary Sphere of Fire-mist.

1. If large, it might undergo annulation — Thus matter for satellites would become isolated. — These must present the same conformities as their primaries in their motions.
2. If small, liquefaction might result without annulation. — Further history. (Lect. XXXIX.)
3. G. H. Darwin's theory of satellite origin by disruption of the primary. (*Nature*, XXI., 235-7, Jan. 8, 1880; *Phil. Trans.*, 1879.)

VI. Confirmations of these Deductions.

1. The evidences of former high temperature in the earth. (Lect. II.)
2. The community of conditions in the solar system.
3. The necessary action of physical forces.
4. The present existence of the assumed fire-mist condition.
5. The present existence of the ring condition.
   (1.) In certain nebulæ. (Lecture XLIII.)
   (2.) In the Saturnian system.
6. The experiment of Plateau. (*Taylor's Scientific Memoirs*, Nov., 1844; *Vestiges of Creation*, p. 14.)
7. The agreement of the cosmic mechanism with the requirements of the theory.
8. The present conditions of Jupiter, the sun and the moon.

9. The exterior planets generally the larger and the less dense.
10. The absence of any fatal conflicts with facts.

VII. Difficulties of the Nebular theory as enunciated by Laplace. (D. Kirkwood, *P. A. Phil. Soc.*, xviii., 324-6, Sep. 19, 1879; *Monthly Notices Roy. Astron. Soc.*, Jan., 1869. Comp. Slaughter: *The Modern Genesis*, 1876, and the author of *The Plurality of Worlds*, ch. vii., Am. ed., 1854.

1. Does not clearly explain breadth of intervals between planetary orbits. (Newcomb: *Pop. Astron.*, 498.) — Suggestion that the plants may be nearly of the same age. (Newcomb, 498–9, 513.)
2. Time required for spheration of a ring extravagantly large.
3. Hence, formation of satellites before cooling involved in difficulty.
4. Period of nebular rotation decreasing as square of radius, ($t : t' :: r^2 : r'^2$), the periods of the planets, ($t : t' :: r_2^3 : r'^3_2$, by Kepler's third law) are *too long*. — This difficulty removed by supposing the peripheral portion rotated more rapidly than the interior, and thus suffered retardation.
5. The asteroids together (as far as known) only $\frac{1}{4}$ the earth's mass, or 1-1200 that of Jupiter, while Mars is also smaller than the earth. — But a portion of the asteroids may have been precipitated into the solar mass again, before the latter had shrunken to dimensions sufficiently within the perihelion position of the asteroidal mass. So of Mars. (Kirkwood, *A. J. S.*, III. i., 71.)
6. General agreement of opinion, nevertheless, in some kind of a nebular origin, with accompaniment of rotation. (David Trowbridge, *A. J.* S., Nov., 1864; Ennis: *Origin of the Stars;* Pierce, in *Agassiz' Contributions to Nat. His. U. S.*)

XLI. IMPLICATIONS OF THE NEBULAR THEORY.

I. Exclusions.

1. It is not, as here contemplated, a theory of the evolution of the universe.
2. It does not involve the comets, ~~as the Laplacean theory did.~~
3. It does not deny an antecedent history for the fire-mist.
4. It does not profess to discover the origin of things, but only a stadium in material history.
   (1) Its starting point postulates ***matter*** and ***force***.
   (2) It leaves us to search still for the ***origin*** of these.
   (3) It affirms nothing concerning the ***nature*** of matter and force.
5. It does not deny the existence of *plan* and *purpose* in the system of cosmic evolution.
6. The truth of the theory can be tested only by scientific evidence.

II. **All the bodies of our System pass the same succession of Phases.** (W. *Geology of the Stars;* Ennis: *Origin of the Stars;* Meunier: *Le Ciel géologique*).

1. The history of each of these bodies a history of cooling.
2. The phase reached at any epoch determined by the age and the mass and volume of the body.

(1) Temperature of the Sun, (J. H. Lane, *A. J. S.*, II. 1, 57):
Secchi, 10,000,000°C, (*A. J. S.*, III. iii, 239); — Ericsson, 4,036,000°, (*Nature*, v. 344, Apr. 25, 1872; *A. J. S.*, III. iv. 152–5). — Zöllner, 400,000°. — Spörer, 27,000° C. — Dewar, 16,000°, (*Proc. Roy. Soc., Edinb.*), vii, 697; *A. J. S.*, III, v. 153). — W. Thomson, 14,000°, (Comp. *A. J. S.*, III, ii, 286). — Faye, 3,000° to 10,000°, (*Comptes Rendus*). — Vicaire, 3,000° C., (*Comptes Rendus*). — Deville, 2,500 to 2,800° C, (*Comptes Rend.*). — Poullet 1,461° to to 1,761° C.

(2) The Earth has reached the habitable condition.

(3) The Moon has passed this condition. — The Earth's mass being 84 times that of the Moon, it had 84 times as much heat. — Its surface being 13.4 times as great it radiatad 13.4 times as fast. — Hence the moon cooled 6¼ times as fast, and each of its stages endured 4-25 as long as the earth's corresponding stage. (Frankland: *Proc. Roy. Ins.*, iv, 175; Guillemin: *The Heavens*, 143; Meunier: *Le Ciel geol.*).

(4) Mars must be in a state of senescence. — Both older and smaller than the Earth.

(5) Venus cannot have reached the habitable stage. — Intensity of solar heat retards its cooling and dissipates the supply of water. — The same with Mercury.

(6) Jupiter lingers in the stormy stage. — Enveloped in aqueous vapor. — Bulk overesti..ated, and hence density underestimated, being placed at one-fourth that of the earth. — Indications of inherent luminosity.

(7) The Saturnian system perpetuates the annular phase. — The rings neither solid nor fluid. (Pierce,). — They seem to be of the nature of dust.

3. The Sun's physical constitution. (Newcomb: *Popular Astronomy*, 237–82; Secchi: *Le Soleil;* S P. Langley, *A. J. S.*, III, vii, 37; ix, 192; x, 459; W. A. Norton, *A. J. S*, III, i, 395.

(1) As old as Neptune, but less cooled in consequence of its great mass. — Will be as dense as the earth in 12,000,000 years. (Newcomb, 573).

(2) Internal solar activities arising from the cooling process. — Spots. — Prominences. — Hydrogen flames. — Corona.

4. The Cosmical Archetype.

III. **Other Worlds Habitable**. (Brewster: *More Worlds than One;* Proctor: *Other Worlds than Ours;* C. Flammarion: *La Pluralité des Mondes Habités*, 8vo., 1864; *Les Mondes imaginaires et les Mondes réels*, 8vo., 1865; Fontenelle: *Dialogues on the Plurality of Worlds*, 1686, 2d ed. 1719. Also, Christian Huygens: *Cosmothereos, sive de Terris Cœlestibus, earumque ornatu, conjecturæ.* Huygenii Opera tom. ii, 645–722, Eng. trans., *The Celestial Worlds discovered, or Conjectures concerning the Inhabitants, Plants and Productions of the Worlds in the Planets*, 1698, 2d ed. 1722, Giordano Bruno:

Universo e Mondi innumerabili; Chalmers: *Astronomical Discourses*, Disc. IV; Bentley: *Boyle Lectures*, Lect. viii, ed. 1724, p. 298 *seq;* Laplace: *Sys. du Monde*, liv. 5me., ch. vi; Derham: *Astrotheology*, 3d ed. 1717, pp. xlvii, liii; liv).

1. Each planet of our system passes a habitable stage. — Terrestrial conditions reproduced on other planets.
2. Climates and supposed vegetation of Mars.
3. Some of the larger satellites possibly habitable.
4. Planets in many other systems may have attained the habitable stage.
5. Nature's economy of habitable conditions.
6. Habitability for peculiar beings may exist where we cannot expect it. (Brewster: *More Worlds than One;* R. Owen: *On the Nature of Limbs*, 1849, Lond., 83, 84. Compare Newton: *Optics*, ed. 1721, 378, 379; Jules Boiteau: *Letters to a Materialist on the Plurality of Inhabited Worlds; The Catholic World*, Feb. 1880, 665–75 from *Revue des Questions Scientifiques*, July, 1877).
7. Some noteworthy conjectures.
   (1) D. Lardner argued the habitability of the moon and all the planets. (*Museum of Science and Art*, vol i.)
   (2) D. Brewster advances similar opinions. (*More Worlds than One*).
   (3) W. Herschel thought the solar spots the highest points (some 600 miles high) of a cool and habitable globe. — The solar heat attempered "in some mysterious way." — Earlier advocates of this opinion. (Pres. Forbes: *Reflections on the Sources of Incredulity with regard to Religion*, Edinb., 1750, p. 3; Dr. Elliot, *Edinb. Encyc.*, Art. Astron., vol. ii, p. 616; *Gentlemen's Magazine*, 1787, 636. Also works of Flammarion, Jean Reynaud, Babinet, Pioger.
8. Habitability of other worlds denied on theological grounds. Maxwell: (*Plurality of Worlds*, 1820, who holds that the Newtonian philosophy contains principles "which lie at the foundation of all atheistical systems)."
9. Denied on scientific grounds. (Whewell: *Of the Plurality of Worlds*).

IV. Many other Worlds Uninhabitable. (Faye: *Annaire du Bureau des Longitudes;* Newcomb: *Popular Astron.*, 516–19).

1. Most worlds probably too old or too recent for habitability. — At least in unsuitable stages of development.
2. All in the solar stage too intensely heated.
3. Question concerning our remoter planets.
   (1) Light and heat of Neptune 1-900th of what we enjoy. — The sun the size of Jupiter to us.
   (2) Density of Jupiter stated at one-fourth that of the earth. — A mere globe of water. — But the weight of bodies two and one-half times as great. — The density probably underestimated.
   (3) Saturn and his dust-like rings.

V. Some Cosmical Finalities.

1. Total refrigeration. (Lyell: *Prin.*, 129; Fourier: *On the Temperature of the Terrestrial Globe and the Planetary Spaces*, Annales de Chemie et de Physique, tome xxviii, 136, Oct. 1824).
   (1) A body is hot only because it has not had sufficient time to cool. — The lava of Jorullo was still ignited after twenty-one years. — That of Aetna, from 1787 to 1830, while unmelted snow remained beneath. Lyell: (*Princ.*, 396).
   (2) No assignable cause for permanent arrest of planetary cooling. — The heat radiated mostly lost to our system. (Fourier, *ut sup*). — Dissipation of energy of a system. (Sir W. Thomson. — This compatible with a total conservation of energy.

2. How uninhabibility may result.
   (1) From attainment of too low a temperature. (W., ch. xxxviii.)
   (2) From the absorption of all water and air. (L. Sæmann as in Lect. XL; S. Meunier: *Le ciel geol.*; W., *Geol. of the Stars*).
      (*a*) The volume of the ocean is only .0042 that of the earth.
      (*b*) Ordinary minerals will absorb .0127 per cent. of water. (Durocher: *Bull. Geol. Soc. France*, II, x, 431. On the porosity of rocks see Hunt: *Chem. and Geol. Ess.*, 164; Delesse: *Bull. Geol. Soc. France*, II, xix, 64: Sorby, *Q. J. Geol. Soc.*, xiv, 1858, 329, 453; D. Brewster: *Ann. de Chem. et de Phys.*, xxi, 1822, 182; *Poggendorff's Annalen*, vii, 493). — Hence the cooled earth would readily absorb all the water of the oceans, and two-thirds of its capacity would remain unfilled,
      (*c*) The volume of the air (reduced to surface density) is .0037 that of the earth. (Sæmann, *ut sup*). — Hence the cooled earth would absorb the atmosphere as well as the ocean, and if as compact as average rocks, would leave five-thirteenths of its pores still unsaturated.
   (3) The water and atmosphere of the moon thus absorbed. (Sæmann, *ut sup.*; W., *Geol. of the Stars;* Guillemin: *The Heavens*, 143; Meunier, *ut sup*). — In cool'ng through 180°, would create cellular space equal to fourteen and a half millions of cubic miles. (Frankland: *Proc. Roy. Inst.*, iv, 175). — Supposed recent changes on moon's surface. (Birt: *A. J. S.*, III, iv, 326).

XLII. COSMICAL DUST.

A. E. Nordenskjöld, On the Cosmical Dust which falls to the Earth with atmospheric preciptation, Poggendorff's Annalen, cli, 154, 1874; *A. J. S.*, III, ix, 145–6; H. A. Newton, *On Shooting Stars*, A. J. S., II, xxxix, 153–207; *ib*, xliii, 285: Schiaparelli, Bolletino Meteorologico Rome, v, Nos. 8, 10, 11, 12, vi, No. 2, abstract, A. J. S., II, xliii, 291–9.

I. Enlargement of the scope of our speculations.

1. Other systems of worlds to be accounted for.
2. Inquiries as to older conditions and other evolutions.
3. Gathering dust. — Examples. — Whence does it come?

II. Meteors (Newton, *as above;*) D. Kirkwood: *A Treatise on Shooting Stars, Fire-balls and Aërolites*, Phil., 1867; Newcomb, Eastman and Harkness, *Observations and Discussions of the November Meteors*, 1867, Washington, 8vo.; 40 pp, 1867.

1. The phenomena (Newton, *A. J. S.*, II, xli, 58, 192, 273, xlii, 429, xliii, 78, 276, xliv, 426, xlv, 78, 225, xlvii, 118, 399, xlix, 244; E. C. Herrick, *A. J. S.* II, xxxi, 136, xxxii, 294, xxxiii, 147, 148, 290, 291).
2. Numbers. — 7½ millions in 24 hours to the naked eye, (Newton, *A. J. S.*, II, xxix, 198). — 400 millions to telescope, (*Ib.* p. 201). — Arago says 240 millions in 3 hours in November, 1833.
3. Contribution of matter to the earth. — 28½ tons daily. — 10,000 tons yearly. — 104 million tons in 10,000 years.
4. Velocity 14 to 107 miles per second. — Meet the earth. — Consequences of penetrating the earth's atmosphere. — Composed of terrestrial substances, (J. L. Smith: *Mineralogy and Chemistry;* Meunier: *Le ciel geol*).
5. Meteoric Swarms and Orbits. (H. A. Newton, *as above;* Schiaparelli, *as above.* A. J. S., III, v, 482; *Entwurf einer Astronomischen Theorie der Sternschnuppen;* Proctor: *Other World than Ours;* D. Kirkwood: *Comets and Meteors*, 1873.
   (1) August orbit fifty times the diameter of the earth's orbit.
   (2) November orbit 33¼ years and ten times the diameter of the earth's orbit. (Newton, *as above;* Sir William Thomson, *Brit. Assoc.*, Edinb.; A. J. S., III, ii, 289, October 1871).
   (3) A hundrd other meteoric orbits more or less known. (Kirkwood, A. J. S., III, vi 392.
6. Space filled with moving meteoroids (Newton).

III. Zodiacal Light. (Newcomb: *Pop. Astron.* 405–6).

1. The Phenomena.
2. Supposed explanation.

IV. Comets. (Newcomb: *Pop. Astron.* 365–84, 398–405; W. Thomson, *A. J. S.* III, ii, 289; Zöllner: *Ueber die Natur der Cometen*, Leipzig, 1872, 8vo., pp. c, 523; *A. J. S.*, III, iii, 476; De la Rue, *A. J. S.*, III, iv, 324; J. C. Watson: *Treatise on Comets.*

1. Conglomeration of cosmical dust. — The matter thought by W. Herschel to be derived from nebulæ. (*Phil. Trans.*, 1812, 144).
2. Not natives of our system. — Their erratic movements.
3. Periods of comets 3½ to 76, and 2,000 and even 100,000 years.
4. Tenuity of their substance.
5. Identification with meteoric swarms. (Newcomb: *Pop. Astron.*, 391–8; H. A. Newton, *A. J. S.*, II, xxxii, 449; Schiaparelli *ut sup.*, and *Monthly Notices*, Feb. 1875; *A. J. S.*, III, ix, 406. Comp. A. W. Wright, *A. J. S.*, III, ix, 459, x, 44; J. W. Mallet, *A. J. S.*, III, x, 206–7).

(1) Comet of 1862 III identified with August swarm. (Newton, Schiaparelli, Oppolzer, Schellen: Spectralanalyse, trans., 600).
(2) Comet of 1866 II. (Tempel's) identified with November swarm. (Schiaparelli, *Les Mondes*, xiii, 501, March 28, 1867; *A. J. S.*, II, xliv, 129).
(3) Biela's lost comet identified with a train intercepted by the earth, November 27, 1872. (But compare *Nature*, xxi, 240, Jan. 8, 1880.
(4) A meteoric ring only a degenerated comet. — Method of gathering cosmical matter into globes.

V. Saturnian Rings.

1. Their physical phenomena.
2. Their physical constitution.

VI. Nebulæ. (Newcomb: *Pop. Astron.* 444–52; Sir Wm. Herschel, *Phil. Trans.*, 1784, 1811, 1814).

1. Description. — Discovery. — Early opinions.
2. So-called "resolvable nebulæ."
3. True nebulæ irresolvable. — Stubborn irresolvability of many nebulæ.
4. The spectroscope. (Schellen: Spectralanalyse, also Amer. transl.; *Half Hour Recreations in Science*, Nos. 3 and 4, Boston; Roscoe: *Spectrum Analysis*, Lond., 2d. ed., 1870, 8vo., pp. 404). — Three fundamental principles of its action. — Application to nebulæ. — The spectra perhaps indicate a state of dissociation. Lockyer's conclusions touching the compound nature of so-called elements. (Nature).

SYNOPTICAL VIEW OF SPECTROSCOPIC PHENOMENA.

DESIGNATION OF SPECTRUM.		CONDITION OF MATTER.
Continuous spectrum	IMPLIES	Incandescent Solid or Liquid. (*Drummond Light.*)
Bright-line spectrum= Discontinuous spectrum= Gas spectrum.	IMPLIES	Incandescent Gas or Vapor. (*Electric Light*; *Solar prominences*; *Irresolvable nebulæ*).
Dark-line spectrum= Absorption spectrum, Reversed spectrum or Compound spectrum.	IMPLIES	Incandescent Solid or Liquid shinging through gas or vapor of lower temperature. (*Sun*; *Fixed Stars*).

5. Forms of Nebulæ.
(1) Amorphous. (Newcomb, 446, 450-1; Schellen: Spec. Anal, trans., 534, etc). — Great Nebula in Orion. (*Nature*, 22 Nov. 1877, 67, and 8 July, 1878, 313.
(2) Sickle-shaped. (Schellen, *op. cit*, 537).
(3) Spiral. (Schellen, *op. cit*, 537).
(4) Spiro-annular. (Schellen, *op. cit*, 540, 541).
(5) Planetary. (Schellen, *op. cit*, 544, 553).
(6) Annular. (Newcomb, *op. cit*, 448; Schellen, 540, 555, 542, also figs., 194, 195).

(7) Stellar. (Schellen, 553). — Compare Donati's comet 1858. (Watson, ; Newcomb, 368; Schellen, 559).

(8) Sir Wm. Herschel's suggestions:—That amorphous, planetary, annular and stellar nebulæ are successive stages in nebular life. (*Phil. Trans.*, 1811, 1814). — Ultimate condensation to a star expected. (*Ib*). — That outlying portions condense into planets. (*Ib*).

VII. General Cosmical Theory.

1. Original world-stuff pervading space. — Suggested to be the ether. (McVicar: *Sketch of a Philosophy;* Saigey: *The Unity of Nat. Phenom*).
2. Gravitational gathering of cosmical dust. — Meteoroidal, cometary and nebular accumulations.
3. Evolutions of nebulæ. — Collisions. — Heat, light, and rotation resulting.

XLIII. NEBULAR LIFE.

Sir William Herschel: *Astronomical Observations relating to the Construction of the Heavens, arranged for the purpose of a critical examination, the result of which appears to throw some new Light upon the Organization of the celestial Bodies*, Philosophical Transactions, 1811, p. 269, and 1814, p. 248. See, also, Philosophical Transactions, 1784. Synopsis of Sir W. Herschel's researches in Newcomb's *Astronomy*, pp. 465–74, 495, and fuller account in Arago's *Analyse des Travaux de Sir William Herschel* in *Annuaire du Bureau des Longitudes*, 142.

Cleveland Abbe: *The "very much extended" Nebulæ of Sir John Herschel's General Catalogue*, A. J. S., III, 1x, 42–6.

I. Isolation and Sources of Nebulæ.

1. Comparative freedom of Nebulæ from perturbations from our system or our firmament.
2. The primitive materials of Nebulæ disseminated and cold. — The materials not all involved in any evolution dating from any specific beginning. — Cosmical beginnings at all times.
3. Process of conglomeration. (Compare Ennis: *Origin of the Stars*, sec. xvi).

II. Origin of Nebular Heat.

1. Theory of Nebular incandescence from condensation. (Comp. Newcomb, *Astron.*, 507, 513). — Limits of applicability of this theory.
2. Nebular amorphism an indication of nebular unions.
   (1) Suggested by our theory.
   (2) Amorphism probably a temporary stage. — Observed changes in nebulæ. (Newcomb: *Pop. Astron.*, 449. Compare Huggins: *On Motions of Nebulæ*, Proc. Roy. Soc., 1874; abstr. *A. J. S.*, III, xiii, 75–7).
   (*a*) The Nebula in Orion. — Changes from Huygens' time to W. Herschel's. (Herschel: *Phil. Trans.*, 1811; Struve: —— ; Holden: *A. J. S.*, III, xi, 360).

(*b*) The Trifid Nebula, M. 20. (Holden: *A. J. S.*, III, xiv, 433–58, Dec. 1777; Newcomb: *Astron.*, 449–50).

(*c*) The Omega Nebula, H. 2008. (Holden: *A. J. S.*, III, xi, 341–61, May, 1876; Newcomb: *Astron.*, 450).

(*d*) The Magellanic Clouds. (Sir W. Herschel, *Phil. Trans.*, 1811).

(3) Apparent changelessness of most nebulæ due to their enormous magnitudes and distances.

3. The impact of nebulæ must generate enormous heat. — This theory, since first propounded, confirmed by James Croll. (*Nature*, Jan. 1878).

III. Origin of Nebular Rotation.

1. This an incident of collision. — The motion of two sole bodies in space. — The motion of three bodies in space.

(1) First Case.—*The centers of gravity of two nebulæ move toward one point with such velocities as to reach it simultaneously.*

(*a*) First sub-case.—*When the centres of gravity move along one straight line.*

(*b*) Second sub-case.—*When the centers of gravity do not move along one straight line.*

(2) Second Case.—*The centers of gravity move toward each other with such velocities as to pass it successively.*

(*a*) When the centers of gravity lie in one straight line.

(b) When the centres of gravity do not lie in one straight line.

2. Rotation also a consequence of superficial currents arising from the passage from an amorphous to a spherical figure. (Ennis: *Origin of the Stars*, sec. xvii; *On the Necessity of Nebular Rotation*, P. A. N. S., Phil., 1867). — How currents would be established. — Retardation by friction with the non-rotating interior. — Friction progressively augmented as density of interior increases.

IV. Origin of Regular Nebular Forms.

1. The Spiral Form may arise from the co-action of an etherial medium in a non-homogeneous nebula.
2. The Sickle Form results apparently from the orbital motion of a nebulous body in a resisting medium. — Illustration.
3. The Spheroidal Form arises in a homogeneous nebula, or from progressive homogeneity in a spiral nebula. — The nebular spheroid the normal form.

V. Differentiation of Nebulæ.

1. Non-rotating nebulæ.

(1) By a process of coagulation.

(2) By condensation about separate centers.

(3) These are possible origins of discontinuous nebulæ. — A state of stellation. — Rotation of the separate masses probable.

2. Rotating Nebulæ. (Comp., Lect. XL, II).

(1) Annulation.

(*a*) The nucleus may separate from the ring. — Example, the Stellar Nebula H. 450.

(*b*) The nucleus may adhere to the ring. — Example, the Annular Nebula in the Lyre. (Schellen: *Spect. Anal.*, 555).

(2) Spheration of annuli. (Comp. Lect. XL, III).

(*a*) By lateral loading on one or more sides.

(*b*) By perturbative rupture.

3. Each constituent mass the mother of a solar system. — The Nebula the mother of a Firmament.

4. Sublimity of these conceptions.

XLIV. OROGENY.

J. D. DANA: *On the Origin of Mountains*, A. J. S., III, v. 347, criticism of J. Hall's theory; see, also, A. J. S., II, xliii, 210. *On Some Results of the Earth's Contraction from Cooling, including a discussion of the Origin of Mountains and the Nature of the Earth's Interior*: Part I, Review of Opinions, and *Theory of Mountain Origin*, A. J. S., III, v. 423–43, June, 1873; Part II: *Condition of the Earth's Interior and Connection of Facts with Mountain-making*, and Part III, *Metamorphism*, A. J. S., III, vi, 6–14; Part IV: *Igneous Ejections*, *ib.*, vi, 104–6, Aug. 1873; Part V: *Formation of Continental Plateaux and Ocean-depressions*, *ib.*, vi, 161–72, Sept., 18 3. Earlier papers, *A. J. S.*, II, ii, 385; iii, 94 176, 380; iv, 88; vii, 379; xxii, 305, 335; also, *Geology U. S. Exploring Expedition*.

JAMES HALL: *Palæntology of New York*. iii., Introduction.

O. FISHER: *On the Elevation of Mountain Chains by Lateral Pressure*, etc. Trans. Camb. Phil. Soc., xi, pt. iii, 1869; *On Elevation and Subsidence*. Phil. Mag., 1872; *On the Formation of Mountains, and the Hypothesis of a Liquid Substratum beneath the Earth's Crust*. Proc. Camb. Phil. Soc., Feb. 22, 1875; *Mountain-making*; *The Inequalities of the Earth's Surface viewed in connection with Secular Cooling*, Camb. Phil. Trans., xii, pt. ii, abstr. A. J. S., x, 380–9.

J. D. WHITNEY: *Mountain Building*.

T. S. HUNT: *Chemical and Geological Essays*, especially, *On Some Points in Dynamical Geology*, (1858), pp. 70–9; *Origin of Mountains*, (1861), pp. 49–58; *Geognosy of the Appalachians, and the Origin of Crystalline Rocks* (1871), pp. 239–327; *Geology of the Alps*, (1872), pp. 328–48; *Criticism of Leconte's Views*, A. J. S., III, v., 264–70.

JOSEPH LECONTE: *Elementary Geology*, 90–132, 252–60; *A Theory of the formation of the Great Features of the Earth's Surface*, A. J. S., III, iv, 345 and 460. Nov. and Dec., 1872, v, 156; *Reply to Hunt's Criticisms*, A. J. S., III, v. 448, June, 1873; *On the Great Lava Flood of the West, and on the Structure and Age of the Cascade Mountains*, A. J. S., III, vii, 167, 259, March and Apr., 1874.

POULETT SCROPE, *Geological Magazine*, vi, 512; F. W. HUTTON, *Mountains*, Geol. Mag.; *Elevation of Mountains and Volcanic Theories*, Nature. ix, 61–2; C. E. DUTTON: *A Criticism upon the Contractional Hypothesis*, A. J. S., III, viii, 112–23. Aug. 1874; also, *Penn Monthly*, May and June. 1876; KARL V. SEEBACH: *Das Mitteldeutsche Erdbeben*, von 6 März, 1872, reviewed by B. K. EMERSON in A. J. S., III, viii. 405–12; FRIEDRICH PFAFF: *Der Mechanismus der Gebirgsbildung*, mit 75 Holzsch., 8vo., 1879.

On the expansibility of rocks by heat, see DANA: *Manual*, 700; TOTTEN: *A. J. S.*, I, xxii, 136; ADIE: *Trans. Roy. Soc. Edinb.*; BABBAGE, *Ninth Bridgewater Treatise*, App. H; F. PFAFF, *op. cit.* and *A. J. S.*, III. x, 235. On contraction in passing from the liquid to the glassy and the stony states, see MALLET, *Trans, Roy. Soc.*, 1872; DELESSE, *Bull. Soc. geol. de France*, II, iv, 1380, 1847.

See also references under Lectures XXIV, XXVI, XXVIII and XXXVIII.

I. Theory of Upheaval by Subterranean Forces. (Studer: *Geologie der Schweiz*).

1. Steam, gases, molten matter or other agents. (Strabo: *Geographia, lib.* vi). — Chemical explanation. (Sir H. Davy, etc.; W. Hopkins, *Report Brit. Assoc.*, 1848; Lect. XXXVIII).

2. Explanation inadequate. (Suess: *Die Enstehung der Alpen*, 165 pp., Wien, 1875, abstr. A. J. S., III, x, 446–51). — These forces too local, and not sustaining. — Mountains do not rest on aëriform foundations. (D., 739). — Nor are they upheld by cores of igneous rocks. (*Nature*, xxi, 177, 25 Dec. 1879). — Nor is the maximum pressure of steam adequate to elevate the crust, or a column of lava in a volcano. (Whitney, *N. Amer. Rev.*, cxiii, 255).

3. Laccolitic mountains a quasi-exception. (G. K. Gilbert: *Rep. on the Geol. of the Henry Mts.*, Powell Surv., 1877; *Nature*, xxi, 177) — Bubbles or blisters raised by intrusive trachytes.

II. Theory of Wrinkling by Lateral Pressure. (Dana. *ut sup.*, and *Man.*, 735, 745; Descartes; *Principes de la Philos.*, pt. iv, § 42.

1. Cause of incipient wrinkles in the earth's crust. — Attributable to lateral pressure. — Effects observed in motion of rocks in quarries. (W. H. Niles, *A. J. S.*, III, iii, 222).

2. Tendency to continual subsequent development.
   (1) Their crests become lines of weakness.
   (2) Lateral pressure would continue to fold in the same direction.
   (3) Influence of deep ocean waters. (Dana). This would tend to parallelize mountain ranges with continental shores.
   (4) Formation of continents and ocean basins. (D. 738).

3. The presence of one fold would predispose to contiguous parallel folds. — Mechanical illustration. — Hence a chain of parallel ranges.

4. The ocean's pressure would result in an excess of thrust away from the shore. (D. 745). — Hence the folds might altitudinally incline continent-ward. — Or might become tilted over. — This possibility often realized. (Lect. XXIV, I, 2,(6)).

5. This theory fulfills requirements of many facts. — But does not explain enormous thickening of strata in mountain-ranges. (Lect. XXIV, I, 5). — Accepted so far as it goes, but requires to be supplemented.

III. Theory of Wrinkling by Mashing Together. (L. 252; Wurtz, A. J. Mining, 25 Jan. 1868, read Aug. 1866; Dana, Mallet, *ut sup.*; Ramsay, Addr. Geol. Sec, Brit. Assoc., 1866).

1. Assumes all the positions of the above theory.

2. Assumes also a thickening of mountain-strata by mashing together. (L. 253).
3. The theory tends to explain metamorphism and igneous phenomena. — Compression the source of heat. (Mallet, Leconte).
4. Mashing might also result from lateral crowding of fluid matter thrust up under the fold. — Attended by thinning along the crest of the fold.
5. This theory explains the thickened strata. — But does not explain their more coarsely fragmental character, and the deficiency of calcareous constituents.
6. The adequacy of secular cooling from shrinkage denied. — Shrinkage insufficient and corrugation too much localized. (Dutton, *A. J. S.*, III, viii, 113; *Penn Monthly*, May and June, 1870). — Shrinkage insufficient and frictional heat too much diffused. (Fisher, *Camb. Phil. Trans*, xii, pt. ii: *Q. J. G. Soc.*, xxxi, 471–2, 473–6). — But some shrinkage is a fact. whatever the cause, and great tangential strain hardly disputable. (L. 260). — Suggestions that the molten interior was at first combined with superheated water, and thus more bulky. (Fisher, *Camb. Phil. Trans*, xii, pt. ii).

IV. **The Synclinorium Theory.** (D., 748–50, 211–14, 244, 251, 275, 305; L. 252–6. Comp. King, 40 *Par.* i, 731; Hunt, *A. J. S.*, II, xxi, 392, 1861; *Chem. and Geol. Ess.*, 49–58; Vose: *Orographic Geol.*; Whitney, *N. A. Review*, cxiii, 265).

1. Starts from the evidences of excessive sedimentation along mountain axes. (Hall: *Pal. N. Y.*, iii, Introd., 69 *seq*).
   (1) These evidences generally admitted conclusive.
   (2) Character of mountain-sediments implies excessive deposition, and proximity of a continental shore. — Principle of distribution of sediments. (Lect. VI, iv.)
2. And recognizes the proofs of progressive subsidence during accumulation.
   (1) Without subsidence, the sea along the axis of deposition would become so shallowed that deposition would cease.
   (2) Subsidence often regarded a mechanical effect of local loading of the crust. (Hall: *ut sup.*).
   (3) But this view untenable. (Fisher, *Geograph. Mag.*, x, 248). — A belt of crust yielding under a foot of sediments would not uphold a mountain mass. — Subsidence, in some cases, has accompanied unloading, and upheaval has accompanied loading. (King: 40 *Par.*, 537, 732).
3. It admits whatever mashing together may have been possible.
4. It admits the mechanical origin of more or less heat, as manifest in the phenomena of vulcanicity.
5. And, finally, it recognizes inherent internal heat as a probable factor.

6. The mechanics of the final uplift of a synclinorium not fully understood. (D. 749; Leconte).
   (1) The synclinorium seems to have been a fact.
   (2) The uplift seems to have been a fact. (L. 242–4, 255–6). — Hall's theory does not provide for this. (Dana, *A. J. S.*)
   (3) Softening or fusion of lower portion of synclinorium a suggested condition of upheaval. (Dana). — But the very condition of softening is the existence of an overlying accumulation, maintaining the original thickness and consequent rigidity.
   (4) Consideration of the mechanical conditions existing about a synclinorium.
      (*a*) Structural arrangement on completion of the synclinorium.
      (*b*) Structural arrangement after uplift of the synclinorium into an anticlinal.
      (*c*) The problem is to ascertain the mechanical conditions of passage from the one to other.
      (*d*) Possibility of a synclinal mountain-mass resulting from mashing together without upheaval of synclinorium.

XLIV. THEORY OF CONTINENTAL GLACIATION.

L. Agassiz: *Systeme Glaciare*; James Croll: *Climate and Time*, 12mo., 577 pp., Am. ed. 1875; (Criticism of this by S. Newcomb, *A. J. S.*, III, xi, 263). Lehon: *L'Homme Fossile*, Part II; Col. Drayson: *Probable Cause, Date and Duration of Glacial Epoch*, Philosophical Magazine, 1871, abstr. A. J. S., III, ii, 304.

I. Recurrence of Phenomena of Glaciation. (Croll, *Climate and Time*, ch. xviii).

1. Summary of phenomena of last glaciation.
2. Similar phenomena of remoter date.
   (1) Worn and transported boulders in the Cambrian. (Jas. Thomson, *Brit. Assoc*, 1870, 88).
   (2) Lower Silurian indications. (J. Carrick *Q. J. G. S.*, v. 10; *Phil. Mag.*, Apr., 1865, 289; Geikie: *Great Ice Age*, 512; Jukes: *Manual of Geol.*, 421; Haughton, in McClintock's *Narrative of Arctic Discoveries*; *Q. J. G. S.* xi, 510.
   (3) Smoothed rock-sufaces and shingle in Medina Epoch. (Hall).
   (4) Devonian indications. (Ramsay, *Reader*, 12 Aug. 1865; Cumming: *History of I. of Man*, 86; Selwyn: *Phys. Geog. and Geol. of Victoria*, 1866, 15–16; Taylor and Etheridge, *Geol. Surv. Victoria*, Quarter-Sheet 13 NE)
   (5) Similar phenomena in the Permian. (D. 431: *Amer. Nat.*, iv, 560; Ramsay, *Q. J. G. Soc.*, xi, 197; Sutherland, *Q. J. G. Soc.*, xxvi. 514; Daintree: *Geol. Dist. Ballan, Victoria*. 1866, 11).
   (6) In the Triassic. (T. A. Conrad and H. Wurtz, 1869; Dana, *A. J. S.*, III, ix, 315; Fontaine, *A. J. S.*, III, xvi, 236).
   (7) In the Jurassic. (Fontaine, *A. J. S.*, III, xvi. 236). — In the Upper Oölite of Scotland. (Judd, *Q. J. G. Soc.*, xxix; *Phil. Mag.*, xxix, 290).
   (8) Between Middle Cretaceous and Lower Eocene. (Dawson, *Princeton Rev.* March, 1879, 284). — In English Cretaceous. (Godwin Austen, *Q. J. G. Soc.*, xiv. 262; *Brit. Assoc. Rep.*, 1857, 62; *Q. J. G. Soc.*, xvi, 327; *Geologist*, 1860, 38).
   (9) A cold period at base of English Eocene. (*Nature*, 10 July, 1879, 258). — The *Flysch* of Switzerland. (Lyell: *Prin*).
   (10) In the Miocene. (Gastaldi. *Mem. Acad. Sci. Turin*, II, xx).

(11) Croll's extension of the idea to the Coal Measures. (*Op. cit.*, 296-8, and ch. xxvi.)

II. **Hypothesis of passage through cold regions of space.** (Lyell: *Prin.*,, 127; Poisson: *Théorie math. de la chaleur*, Comptes Rendus, 30 Jan. 1837; Agassiz: *A Journey in Brazil*, 399, 425). — Or that the sun has experienced a diminution of heat. (Lyell: *Prin.*, 128; Sir John Herschel, *Proc. Roy. Astron. Soc*, No. iii, Jan., 1840; Balfour Stewart). — Both would involve simultaneous lowering of temperature over all parts of the earth. (D. 542. Compare Hopkins, *Q. J. G. Soc.*, viii).

III. **Theory of the varying distribution of land and water; and consequent changes of marine currents.** (D. 541: Lyell: *Prin.*, ch. vii, viii; Dawson, *Princeton Rev.*, Mar. 1879). — Northern elevation. (D. 541; *A. J. S.*, III, ix, 314-5, II, xxii, 346). Closing of Behring's Strait and submergence of Isthmus of Panama. (D. 541). — A true cause, but, to be of sufficient magnitude, would conflict with evidence of permanence of oceanic and continental areas. — The requisite distribution of northern land to produce the known glaciation, difficult to conceive. — The effect of placing all the land along the equator would be the opposite of what Lyell supposed. — The theory not suited to explain a succession of ice periods at secular intervals. — Northern elevation itself perhaps an effect of the real cause.

IV. **Suggested change in the power of the atmosphere to transmit terrestrial heat.** (D. 542; Tyndall; Hunt). — Cold of mountain elevations. — This, also, would affect all regions similarly.

V. **Astronomical Theories.** — Secular variations in the elements of the earth's orbit. (Stockwell, *A. J. S.*, II, xlvi, 87. See, also, *A. J. S.*, II, l, 147. Also, Meech, *Smithsonian Contributions*, ix, Art. i, Sec. vii). — Discussion in reference to Northern Hemisphere. — Researches of Humboldt, Arago, Sir J. Herschel, Lyell and Croll.

1. Effect of changes in the obliquity of the ecliptic. (Drayson, *Q. J. Geol. Soc.*, xxvii, 232; *The last glacial epoch of geology*; Thos. Belt, *Q. J. G. Soc*, Oct. 1874, abstr. *A. J. S.*, III, ix, 313-5).
   (1) Increased obliquity diminishes glaciation.
   (2) Diminished obliquity increases glaciation.
   (3) This cause insignificant, and now abandoned. (Croll: *Clim. and Time*, ch. xxv; Georgé Darwin).
2. Possible shifting of position of terrestrial poles. (Sir W. Thomson, *Brit. Assoc. Rep.*, 1876, pt. ii, p. 11; *Trans. Glasgow Geol. Soc.*, iv, 313; Haughton, *Proc. Roy. Soc.*, xxvi, 51: Geo. Darwin,

Trans. Roy. Soc., clxvii, pt. i ; I. F. Twisden, *Q. J. G. Soc.*, Feb. 1878 ; Airy, *Athenæum*, 22 Sep. 1869).

(1) This also an insignificant cause. — To displace the pole 1° 46′, one-twentieth the surface of the earth must be lifted 10,000 ft. (G. H. Darwin).

(2) Since the glacial epoch, no physical changes have occurred which could move the pole six miles. (Cr ll, *Geol. Mag.*, Sept. 1878).

(3) Geological evidences exist that the pole has not changed since Silurian time. (Haughton, *Proc. Roy. Soc.*, Apr. 4, 1878 ; *Nature*. July 4, 1878 ; E. Hill, *Geol. Mag.*, June, 1878 ; Croll, *Geol. Mag.*, Sep. 1878; W. Thomson, *ut sup*).

(4) Dynamical principles show the present axis a necessary permanency. (Sir W. Thomson, *ut sup ; Brit. Assoc.*, 1874).

3. Effect of precession of the equinoxes, or change in position of the apsides. (Adhémar : *Revolutions de la mer ;* Le Hon : Periodicité des Grandes Déluges, 1858).

(1) Winter solstice in perihelion diminishes glaciation. — Opposite view entertained by J. J. Murphy. (*Q. J. G. Soc.*, xxv, 350).

(2) Summer solstice in perihelion increases glaciation.

(3) This cause alone also insufficient. — Croll now says null. (*Clim. and Time*, 83 ; *Phil. Mag.*, Sep. 1869 ; Arago, *Edinb. New Phil. Jour.*, vi, 1834).

1. Effect of change in eccentricity of earth's orbit.

(1) Increased eccentricity increases glaciation.

(2) Diminished eccentricity dimishes glaciation.

(3) This cause alone regarded as inefficient. (Sir J. Herschel, *Treatise on Astronomy*, § 315 ; *Outlines of Astronomy*, § 368 ; Arago, *Annuaire* for 1834, p. 199 ; *Edinb. New Phil. Jour.*, Apr. 1834, p. 244 ; Humboldt : *Cosmos*, iv, 459, Bohn's ed. ; *Phys. Descrip. Heavens*, 336).

(4) Croll connects this with consequent changes in ocean currents. (Croll : *Clim. and Time*, etc. See brief abstract by Croll in *A. J. S.*, III, xvi, 389, and a fuller one by A. Winchell in *International Review*, July-Aug., 1876).

(*a*) Changes in eccentricity produce little or no *direct* effect.

(*b*) Increased eccentricity produces] diminished winter heat and this promotes snowy precipitation. — The prolongation of the winter thus only increases the snow. — The short, hot summer would not diminish it. — Heat absorbed in liquefaction. — Fogs and vapors exclude solar rays.

(*c*) Effect of this upon ocean currents :—Prevailing winds the cause of ocean currents. (Croll : *op cit.*, ch. ii, iii, xiii). — Maury's theory. (Maury : *Phys. Geog. Sea*, § 24). — Appears to be untenable. (Croll : *op cit.*, ch. vi, vii). — Carpenter's theory. (Carpenter, *Proc. Roy. Soc.*, Dec. 1868, Nov. 1869 ; *Nature*, i, 490 ; *Proc. Roy. Geogr. Soc.*, xv). — Also untenable. (Croll ; *op cit.*, ch. viii, xi).

Why the region of calms is now north of the equator. — The condition supposed would place it south. — This would direct the Gulf-Stream southward. (Croll : *op cit.*, ch xiv).

(*d*) European cold caused by diversion of Gulf-Stream.

(5) Such a theory when established would furnish a clew to geological time. (Croll : *op cit.*, ch. xix. Lecture LIII, IV).

(8) Criticisms of Croll's theory. (J. J. Murphy, *Q. J. G. Soc.*, xxv, 350, 1869, abstr. *A. J. S.*, II, xlix, 115-8 ; S. Newcomb, *A. J. S.*, III, xi, 263 ; Chas. Martins, *Revue des deux Mondes*, 1867).

VI. Displacement of Earth's centre of gravity by an ice-cap. (Croll, *op. cit.*, ch. xxiii, xxiv; Adhémar: *Revolutions de la mer.* Comp. Shaler, *Mem. Bos. Soc. Nat. Hist.*, ii, 322). — Submergence an incident of glaciation.

XLVI. MOTION OF GLACIERS.

L. Agassiz: *Systeme Glaciare*, 1847; James Croll, *Philosoph. Mag.*, March, 869, Sep. 1870; *A. J. S.*, III, i, 65–68; *Climate and Time*, ch. xxx, xxxi; Canon Moseley, *Proc. Roy. Soc.*, 7 Jan. 1869; *Phil. Mag.*, May, 1769, Jan, 1870, Aug. 1871; *A. J. S.*, III, ii, 304; Albert Heim, *Poggendorff's Annalen*; *Phil. Mag.*, June, 1871; *A. J. S.*, III, ii, 145; W. Mathews, *Alpine Journal*, Feb, 1870; *L., E. and D., Phil. Mag.*, Dec. 1871, Jan. 1872; *A. J. S.*, III, iii, 99; Ball, *Phil. Mag.*, July, 1870, Feb. 1871; *A. J. S.*, III, i, 268; James D. Forbes: *Occasional Papers on the Theory of Glaciers*; John Tyndall: *The Glaciers of the Alps*, 1860; *The Forms of Water*, 1872; John Aitken, *Nature*, 13 Feb. 1873; *A. J. S.*, III, v, 305.

I. Nature of the motions of Glaciers. (Ref. Lect. XVIII).

1. More rapid in the middle than along the borders.
2. More rapid at the surface than at the bottom.
3. More rapid by day than by night.
4. And twice as fast in summer as in winter.
5. The glacier adapts itself to the inequalities of the channel.

II. Theory that the Glacier moves by Expansion and Contraction. (L. Agassiz; Charpentier; Moseley, *Proc. Bristol Naturalists' Soc.*, 1869).

1. Effect of expansion of a slab on an inclined plane.
2. Effect of contraction of the same.

III. Theory that it moves as a Viscous Body. (D. 682; L. 57; Bordier, 1773; Rendu; *Mem. Acad. Sci., Savoy*, 1841; J. D. Forbes: *Travels in the Alps*, 1843; *Occasional Papers*).

1. Arguments for this theory.
2. This does not explain seasonal and diurnal variations in the rate of motion.

IV. Theory of motion by Regelation. (L. 58; Tyndall, *Phil. Trans.*, cxlvii, 327; *Glaciers of the Alps;* James D. Forbes, *Proc. Roy. Soc.*, viii, 455; Helmholtz: *Popular Lectures*, 133, *seq*).

1. Definition of regelation. (Tyndall: *Heat as a mode of motion*, 167–72).
2. Faraday's explanation of regelation. (Tyndall: *Forms of Water*, 173). — Molecular attractions more solidifying in the centre than at the surface. — Hence two liquefying surfaces brought together solidify because made internal.
3. James Thomson's explanation. (*Proc. Roy. Soc., Edinb.*, Feb. 1850; Tyndall: *Hours of Exercise*, 383, *seq.*; Jamin: *Traité de Physique*, ii, 105; Helmholtz: *Popular Sci. Lectures*, Am. ed., 107–152, es-

pecially 133). — Pressure, consequent melting, and refreezing on removal of pressure. — Requisite pressure is in some cases absent.

4. Final explanation. (Croll: *Clim. and Time*, 557; Tyndall: *Hours of Exercise*, 365, 384). — Two melting surfaces brought into contact assume the condition of an *interior* film, where the icy state is maintained.

5. Regelation explains persistent continuity of the ice, but not the *motion* which *precedes*, and is the condition of regelation.

V. Theory of Motion by Molecular Melting and Refreezing. (Croll: *Phil. Mag.*, March, 1866, Sep. 1870; *Clim. and Time*, ch. xxxi).

1. A molecule at the instant of receiving heat above 32°, liquefies and flows into the most accessible interstice.
2. But it instantly transmits its heat to the next molecule and refreezes. — In refreezing it requires more space, and creates an expansive tendency of the mass.
3. This next molecule similarly liquefies, flows, transmits and refreezes. — Each succeeding molecule, in turn, behaves similarly.
4. Thus the ice-mass is transferred molecularly to lower levels. — Erosion is effected by the molecular transfer, and by the molar motion resulting from expansion.
5. Difficulties of this theory.
   (1) The proof cited to establish transmission of heat through ice confounds diathermancy with conductivity.
   (2) When one molecule melts, a whole layer would melt simultaneously. On transmitting their heat to the next layer, that would melt; but the first layer would *not* recongeal, in consequence of a new accession of heat. Thus the *conduction* of heat through a mass at 32° would liquefy it wholly or partially, and it would *not* recongeal.
   (3) Molecular movements would not produce geological denudation.

VI. Present state of Theory.

1. Ice, like wax, molasses-candy and many other substances, is brittle under a momentary force, but yields molecularly under a continued pressure. — It is so far a fluid, and like all fluids would adapt itself to inequalities.
2. It has not been shown that a *slight* pressure, even its own gravity, is not sufficient to produce the phenomenon of "shear," or molecular over-slipping. — It may be presumed that gravity would suffice. — Canon Mosely's assumption of a high "index of shear" not admitted.

3. The residual molecular cohesion would tend to cause the ice to move, to a partial extent, as a rigid mass. — It would therefore *erode*.
4. All refreezing or regelation in the interior spaces and interstices would develop an expansive tendency which would augment both terminal motion and erosive action, and would help the freer border of the ice over hindrances to motion. — Hence more rapid motion when thawing introduces water into the icy spaces.
5. Crevassing results from an abrupt strain which the waxiness of the ice has not *time* to respond to. — A gentler change of slope affords more time, and may avoid crevassing. (Comp. Aitken, *A. J. S.*, III, v. 305). — Tyndall's contrary opinion. (L. 59; Tyndall: *Hours of Exercise*, etc).
6. Grains of truth in most of the theories.

XLVII. CAMPESTRAL FORMATIONS.

Superficial deposits spread out in generally treeless, but sometimes forest-covered, plains.

I. Löess.

1. Review of geographical distribution. (Pumpelly, *A. J. S.*, III, viii, 133; Aughey, *Hayden Ann. Rep.*, 1874, 245–50; *Sketches of Nebraska*, 1880, 280–4); v. Richthofen: *China*, 56–74, 152–189.
2. Its geological position.
3. Physical characters. (v. Richthofen). — Color. — Fineness. — Calcareity. — Cylindrical perforations. — Fossil remains.
4. Theories of sedimentary origin, marine, lacustrine or fluviatile. (Aughey, *ut sup.*; Kingsmill, *Q. J. G. Soc.*, 1871, 376; v. Richthofen, 162–8).
   (1) Grounds. (Gümbel: *Geognost. Beschreibung des Bair. Alpengebirges*, 1861, 798; 805, 852, 872; Fallou: *Ueber den loess*, Jahrb. f. Min., 1867. 143–58).
   (2) Difficulties of these theories.
5. Theory of glacial and torrent origin. (Lyell: *Antiquity of Man*, ch. xvi).
6. Theory of sub-aërial origin. (Richthofen: *China*, 74–84; Pumpelly, *A. J. S.*, III, viii, 133). — This theory opposed. (Jos. Leconte, *A. J. S.*, III).

II. Arid Plains.

1. The "Great Plains" of the trans-Mississippi.
   (1) Their physical characters.
   (2) Their topography.

2. Treelessness generally due to aridity.
   (1) Meteorological data.
   (2) Results of irrigation.
3. Influence of alkalinity in the soil.
4. The plains of the "Plateau" and "Basin" regions of the U.S.

III. **Marshes, Bogs, Wet Plains, Swamps, Heaths.**

1. American Bogs or Swales.
   (1) Treeless. — Grass-covered. — Level. — Peaty. — Generally underlaid by marl.
   (2) These evidently the beds of ancient lakes. — Wetness the residuum of the lake-water. — Destined to be expelled by further additions of solid matters.
2. Wet lands underlaid by "hard-pan."
   (1) The "Landes" of Gascony, the "Campine" of Belgium, the Heaths of Holland and Germany. (Reclus: *Earth*, ch. xiii; Emil de Lavaleye, *Revue des Deux Mondes*, June, 1861). — Some pine-covered plains in Prussia and the United States.
   (2) Regions underlaid by a ferruginous film of concreted sand. ("alios" of Gascony or "jernal" of Jutland). — Sufficiently elevated, but being without slope, and impervious below.

IV. **Sandy Steppes and Tundras.** (Comp. Humboldt: *Steppes and Deserts*, in *Views of Nature*).

1. Steppes of the Dnieper. — Steppes of the Caspian and their aridity. (v. Baer: *Kaspische Studien;* Zaleski; *La vie des steppes Kirghizes*). — Winter aspect. — Tundras of northern Siberia.
2. These regions recently sea-covered. — Brackish and alkaline. — In northern Siberia permanently frozen at shallow depths.

V. **Treeless Prairies, Savannas, Grassy Steppes.**

1. Prairies of Illinois. — The "Polders" along the coast of the German Ocean. — The Magyar "Puszta." — The "Tchornosjom" or Black Earth of Russia, stretching from the Black Sea northeast, and covering an area twice the size of France. (Ruprecht: *Bullet. de l'Académie de St. Petersbourg*, vii, No 5). — Plains or "Steppes" of southern Siberia. (Humboldt: *Asie Centrale and Tableaux de la Nature*). — "Llanos" of Columbia. — "Pampas" of the La Plata. (Humboldt: *Tableaux; Voyage dans les Regions equinoxiales*).
2. Theories of Origin of Illinois Prairies. (W., 264–72; *A. J. S.*, II, Nov. 1864).
   (1) Treelessness caused by annual burnings. (*A. J. S.*, I, i, 331). — Generally abandoned.
   (2) Caused by choking out by the tangled roots of cane. (*A. J. S.*, I, xxiii, 40), — Cane does not grow in Illinois.
   (3) Caused by excessive dryness of climate. (D., 44; Cooper, *Smithson. Ann. Rep.*, 1858, 276; Newberry, *Ohio Agric. Rep.*, 1859; Lambert, *Pacific R. R. Rep.*, i. 166). — The treeless plains of the west probably originated, in part, from such cause. — But in Illinois, trees grow when planted.]

(4) Caused by excessive humidity of soil. (Atwater, *A. J. S.*, I, i, 116; Bourne, *ib.*, ii, 30; Lesquereux, *2d Ark. Geol. Rep.* Also, *Western Monthly Mag.*, Feb. 1836; Engelmann, *A. J. S.*, II, xxxvi, 384). — Objected that the Illinois prairies are *not* generally wet. — That certain appropriate trees often occupy wet situations. — That in Illinois trees grow when introduced.

(5) Caused by extreme fineness of the soil. (J. D. Whitney, *Iowa Geol. Rep.*, i, 24; *New Amer. Cyclopæd.*, Prairies). — Wanting in evidence. — Trees do grow when introduced. (Wells, *A. J. S.*, I, i, 331; Engelmann, *ib.*, II, xxxvi, 389; Edwards, *Dep. of Agric.*, 1862, 495; C. A. White, *Geol. Iowa*, 1868, 166. See also, *Prairie Farmer*, Chicago, *passim*; Gerhard: *Illinois as it is*, 277).

(6) Geological theory. (W., 241-72; *A. J. S.*, II, Nov. 1864).

(*a*) The prairie soil a lacustrine formation. — Physical characters. — Fresh-water shells. — Former high level of the Great Lakes. (Lect. XX, III. 2).

(*b*) Lacustrine sediments inclose but few living germs. (W., *ut sup*).

(*c*) The drift deposits seem to be replete with living germs. — Sudden appearance of unwonted species. (W., *ut sup*).

(*d*) These living germs buried during glacial epoch.

Approximation of Tertiary and even Cretaceous vegetation to modern types. (Lesquereux, *A. J. S.*, II, xxvii, 363; Newberry, *A. J. S.*, II, xxix, 215, *seq.*).

Glacial action must have buried innumerable living germs.

Prolonged preservation of woody tissue. — Maul handles in ancient mines of L. Superior. — Piles of Loudon Bridge and Old Savoy Place, and the city of Venice. — Piles of Trajan's bridge over the Danube. — Piles in the Swiss lakes. — Wheels in Roman mines of San Domingo. — Cedar timbers in N. J. Swamps. (Cook: *Geol. N. J.*, 343, *seq*; Lyell: *Travels in N. A.*, 2d Vis., i, 34). — Timber in saliferous sandstone in S. A. (Orton: *Andes and Amazon*, 116, note). — Found buried with Cohoes Mastodon. (Hall, *App. Rep. N. Y. Regents*). — Prostrate forests beneath diluvium. (Locke, *Trans. Assoc. Amer. Nat. and Geol.*, 240; Worthen: *Geol. Ill.*; *A. J. S.*, II, i, 54). — In the Danish bogs. (*Mem. Acad. Sci.*, Copenhagen, ix, 1842; *Smithson. Ann. Rep.*, 1860, 305, *seq.*; Whittlesey, *Proc. Amer. Assoc.*, 1866, 49). — Wood in Cretaceous sandstone in Ala.

Persistence of vitality of seeds. (W., *ut sup.*; *Amer. Exchange and Rev.*, June, 1870; *Gardener's Chronicle*, Lond.; *Patent Off. Rep.*, 1857, Agric., 256). — Indications of latent seeds in the soil. (*Hist. Brit. Dominions in Amer.*, Lond., 1773; Marsh: *Man and Nature*, 285, *seq.*; Darwin: *Origin of Species*. Am. ed., 69). — Dr. Lindley's raspberry seeds from Hadrian's time. — Wheat from Egyptian mummies. (Carpenter: *Elem. Physiol.*, Am. ed., 41; Draper: *Intellect. Devel. Europe*, 72; L. Agass.: *Prin. Zool.*, 136). — The account doubted. (Asa Gray, *A. J. S.*; Lyell: *Prin.*, 565). — Fresh grape seeds with Cohoes Mastodon. (Hall). — New species of poppy from soil beneath the refuse of the Laurium silver mines in Greece. (Theod. v. Heldreich, Univ. Athens).

(*e*) Flora of the preglacial period reproduced from these germs.

(*f*) But the flora of the prairies must have come from surrounding regions.

(*g*) Coöperation of Indian burnings.

(*h*) This theory criticized. (Geo. Vasey, *Amer. Entomol. and Botanist*, July-August, 1870; Dana, *Amer. J. S.*, II; Lesquereux).

XLVIII. THE QUESTION OF EVOLUTION IN GEOLOGY.

I. Prolegomena.

1. Evolution the progressive differentiation of an identical existence. — The progress of heterogeneity out of homogeneity. — Based on the principle of continuity. (Leibnitz).
2. It is a method, a *mode*, a relation in the terms of succession.
3. A question of *fact*, not of causation or of consequences. — The fact to be ascertained by observation. — The philosophy of causation may be consulted when the fact is known.

II. The Principle of Continuity in the Inorganic World. (W., *The Doctrine of Evolution*, 18–27).

1. All consecutive conditions mutually connected by an infinity of intermediate conditions.
   (1) The formation of a river-delta. — Its growth inch by inch, millimetre by millimetre.
   (2) The development of a continent. — Its surface expanded by infinitesimal stages. — Its final highly differentiated condition reached by passage through all lower degrees of differentiation.
   (2) The formation of the earth. — Differentially progressive in its mode of cooling. — In its process of solidification. — In its sedimentations. — In its denudations. — In its diversification.
   (3) Indications that a material continuity runs back from the present condition of the earth through its cosmical history, and thence through the cosmical history of all the planets, and thence through the totality of cosmical history. (Lects. XXXIX-XLIII).
2. Discontinuity of process inconceivable, except through new creative beginnings.
3. General admission that inorganic history exemplifies the principle of evolution.

III. The Principle of Evolution in Palæontology.

1. Are successive organic types materially (genetically) connected?
2. The general graduation of organic forms. (Lect. XXXI).
   (1) The general tenor of palæontological history.
   (2) The nicely graduated successions in certain instances. (Lect. XXXVI).
3. Apparent breaches of the principle of progress.
   (1) Missing links. (Lect. XXXIV).
   (2) Graduated structures chronologically misplaced. (Lect. XXXV).
   (3) The misplacement sometimes amounting to apparent regress in respect to rank. (Lect. XXXI).
4. These appearances perhaps attributable to the imperfections of our knowledge. (Lect. XXXIV, I).
   (1) Successional gaps may be filled by future discoveries. — The constant tendency of discovery to fill the gaps.
   (2) Chronological misplacements perhaps only local. — In another region the lower terms may have appeared earlier. — Appearances of regression similarly explicable.

(3) The palæontological consequences of changes in ancient faunal distributions.
(*a*) Illustrated by changes now in progress.
(*b*) The record must present for single localities or regions, abrupt transitions, chronological misplacements and taxonomic regressions.
(4) Palæontological consequences of relapses in the material environment of life.
(*a*) Correlation between structure and environment.
(*b*) Structural progress keeps pace with inorganic progress.
(*c*) Cataclysms and local pauses in inorganic progress would condition arrest or regress in organic history.
(*d*) So, sudden improvements in environment might condition secularly sudden improvements in organic structure.

IV. A Material Continuity not proved by Palæontology.

1. Erroneous opinion that palæontology furnishes a "demonstration." (Huxley: *New York Lectures*, 1876; O. C. Marsh: *Nashville Address*, 1877).
2. A perfect graduation of terms compatible with a method of universal discontinuity.
(1) Illustration from products of human efforts. — Wheeled vehicles. — Aquatic vehicles.
(2) Illustrated in the law of chemical homologues.
(4) In the family groups of crystallography.
(5) And even in geometrical forms, as the "conic sections" and the family of triangles.
(5) Hence, each form of life may be conceived an independent origination.
3. But an evolution of the concept palæontologically demonstrated. — And this proves unity of plan, and hence, unity of intelligence.

V. A Material Continuity rendered probable by Palæontology.

1. This hypothesis compatible with all the phenomena.
2. We have the right to reason from the *tenor* of observed facts, as well as from the facts actually known. — Such reasoning implies that apparent gaps were actually filled. — That the graduation was continuous, and that the relation of the terms was genetic.

XLIX. THE QUESTION OF EVOLUTION AT LARGE.

CHARLES DARWIN: *Jour. Linnæan Soc.*, Lond., 1858; *The Origin of Species by means of Natural Selection*, (1758), N. Y., 1860; *The Variation of Animals and Plants under Domestication*, 2 vols., N. Y., 1868: *Expression of the Emotions in Man and Animals*, N. Y., 1873; *The Descent of Man, and Selection in relation to Sex*, N. Y., 1877.

ALFRED R. WALLACE: *Ann. and Mag. N. Hist.*, Sep. 1855; *Jour. Linn. Soc.*, Lond. 1858; *Contributions to the Theory of Natural Selection*, N. Y., 1871.

HERBERT SPENCER: *First Principles of Philosophy*, N. Y., 1865; *Principles of Biology*, 2 vols., N. Y., 1866.

ST. GEORGE MIVART: *On the Genesis of Species*, N. Y., 1871; *Lessons from Nature as manifested in Mind and Matter*, N. Y., 1876; *Contemporary Evolution*, N. Y., 1876: *Man and Apes*, N. Y., 1874.

ASA GRAY: *Darwiniana: Essays and Reviews pertaining to Darwinism*, N. Y., 1878.

T. H. HUXLEY: *On the Origin of Species, or the Causes of the Phenomena of Organic Nature.* N. Y., 1866.

ERNST HAECKEL: *Naturliche Schopfungsgeschichte*, 4th ed., Berlin, 1873, trans. *Nat. History of Creation*, N. Y; *Anthropogenie: Entwickelungsgeschichte des Menschen*, Leipzig, 1874, trans. *The Origin of Man*, N. Y.

H. S. CHAPMAN: *Evolution of Life*, 2d ed., Philadelphia, 1873.

A. WINCHELL: *The Doctrine of Evolution*, N. Y., 1874.

Also DEMAILLET: *Telliamed, ou entretiens*, etc., Amsterdam, 1748, also transl.; LAMARCK: *Philosophique Zoologique*, etc., nouv.-ed., 1873; NAEGELI: *Enstehung und Begriff der Art*; A. KÖLLIKER: *Ueber die Darwin'sche Schopfungsgeschichte*, 1864; E. D. COPE: *Origin of Genera*, Proc. A. N. S., Phil., Oct. 1868; *The Hypothesis of Evolution*, Lippincott's Mag., 1870, and "University Series," New Haven, 1873; *The Method of Creation of Organic Types*, Proc. A. A. A. Sci., 1871; *A Review of the Modern Doctrine of Evolution.* Amer. Nat., Mar. and April, 1880, 166; T. PARSONS, *A. J. S.*, II, xxx, i, July, 1860; R. OWEN: *Anatomy of Vertebrates*, ch. xl; *A. J. S.*, II, xlvii, 33; A. HYATT: *Mem. Bos. Soc. N. Hist.*, I, pt. ii, 1867; *Amer. Nat.*, iv, 230–7, June, 1870; J. D. HOOKER: *Flora of Tasmania*, Introduc. Essay; *A. J. S.*, II, xxix, 1 and 305, Jan. 1860.

I. The Palæontological Evidence. (Lect. XLVIII).

II. The Morphological Evidence.

1. Familiar indications of blood-relationship. — Eminently morphological.
2. Structural relations in the organic kingdoms. — Basis of classification.
   (1) Fundamental plans of structure.
      (*a*) As to ultimate structures. — Cells, membranes, fibres, tissues.
      (*b*) As to general structure. (Lect. XXXI, II; XXXVII, I).
   (2) Fundamental physiological conceptions. — Nutrition, Respiration, Circulation, Neuration, Musculation, Wastage and Repair.
3. Rudimental structures. — Rudiments of structures morphologically interpretable, but functionally useless. — "Dysteleology" of Haeckel.
2. These all indications of genetic connection and common origin.
5. But not a demonstration of such.

III. The Variational Evidence.

1. Arising from Geographical Position.
   (1) As to plants. — Juniper, Paper Birch, Chestnut Oak, Hackberry, Beach Plum, Black Thorn, June Berry, Wild Rose. — Confluence of genera, as *Cardamine* with *Dentaria* on one hand, and *Arabis* on the other.
   (2) As to animals.
      (*a*) Echinoderms. (L. Agassiz, *Proc. Amer. Acad.*, v. 72). — Sponges, (Haeckel: *Die Kalkschwamme*).
      (*b*) Molluscs. (Cooper, *Proc. Cal. Acad. N. Sci.*, v. 28; Barber, *Amer. Nat.*, Sep., 1876, 529; Weatherby, *Proc. Cincinnati Soc. Nat. Sci.*, No. 1, June, 1876; Lewis, *Proc. Bos. Soc. Nat. Hist.*, v. 121-8).
      (*c*) Insects. (A. S. Packard, *Geometrid Moths.* Hayden Surv., x, 42–3; W. H. Edwards: *Butterflies of N. A.*, pt. ix; Walsh, *Proc. Entmol. Soc., Phil.*, iii, 403).

(*d*) Fishes. — Blind fishes of caverns. (F. W. Putnam: *Life in the Mammoth Cave*).

(*e*) Birds. (S. F. Baird, *Pacif. R. R. Rep.*, ix, 1858; *Mem. Nat. Acad.*, Jan. 1863; *A. J. S.*, II, xli, Jan., Mar. and May; J. A. Allen, *Proc. Bos. Soc. Nat. Hist.*, xv, 156; *Bull. Mus. Comp. Zool.*, ii, No. 3, pp. 229–49; *ib.*, iii, July. 1872; *Bull. Hayden Surv.*, ii, No. 4, 345 Aug. 1876, repub. *Amer. Nat.*, Oct. 1876, 625; R. Ridgeway, *A. J. S.*, III, iv, 454, Dec. 1872, v. 39, Jan., 1873, and *Bull. Hayden Surv.*, No. 2, 1875, 58; *Amer. Nat.*, vii, 415, July, 1873. Comp., also, Coues, *Proc. A. N. S.*, July, 1872, 60; *Key to N. Amer. Birds*, Oct. 1872). — Generalizations drawn by Baird, Allen and Ridgeway.

(*f*) Mammals. (Baird, *Pacif. R. R. Rep.*, viii, 1857: Allen, *Proc. Boston Soc. N. H.*, xvi, 276; *Rad. Review*, i. No. 1, May, 1877; *Leporidæ*: Hayden Rep., xi. 4to., 269, 304–323, 645–52; E. Coues, *Muridæ*, Hayden Rep., xi, 4to., 29–31, 32, 40, 65, 73, 75, 185, 189, 240; H. C. Yarrow, *Wheeler Rep.* 4to., v, ch. i).

(3) These variant forms as good species as ever. — The error of abandoning them as species.

2. Arising from changed environment.

(1) The Axolotl or *Siredon lichenoides*. (Duméril; Marsh, *A. J. S.*, II. xlvi, 364; *Tribune Extra*, No. 8).

(2) *Branchipus* and *Artemia*, (Schmaukevitch; Hagen, *Proc. A. A.*, 1876). — These results, however, to be received with caution. (Verrill, *Proc. A. A.*, 1869, 230).

3. Arising from hybridity.

(1) Repeated assertion that hybridity has originated no permanent forms.

(2) Hybrid species of trees enumerated in Floras. (Gray: *Man. Bot. North. U. S.*). — Vegetable hybridity fully established. (A. DeCandolle, *Treatise on Oaks*; Naudin: *Hybridity in the Veg. Kingdom*).

(3) Fertile hybrids of Common and Chinese geese in Mt. Auburn Cemetery, (Youmans, in Quatrefage's *Nat. Hist. of Man*. 143). — Very common in India, and occurring in England, (C. Darwin, *Nature*, xxi, 207, Jan. 1, 1880).

(4) Fertile hybrids of hare and rabbit. (Gindre, *Bull. de la Soc. imp. Zool. d'Acclimation*, 1870, 659–67).

4 Examples among fossil remains.

(1) *Orthis biforata* with varieties *lynx*, *laticosta*, *dentata*, *acutilirata*. (Meek: *Pal. Ohio*, i, pl. x; Hall: *Pal. N. Y.*, i, 133, pl. xxxii D).

(2) *Spirifera disjuncta*, with eighteen varieties. (Hall: *Pal. N. Y.*, iv, pl. xli, xlii).

(3) *Spirifera mucronata*. (Hall: *Pal. N. Y.*, iv, pl. xxiv). — *Atrypa reticularis*, with sixteen varieties. (Hall: *Pal. N. Y.*, pl. li–liii; Whitfield, *XIX Rep. N. Y. Regents*). — *Pentamerus Knightii*. (Davidson: *Brit. Foss. Brachiop.*).

5. Rudimentary structures result from variation.

6. The facts of Variability demonstrate the *possibility* of a material continuity between species.

IV. The Embryological Evidence.

1. Nature of the embryological succession. — We can indicate twenty-two, or more, stages in the development of highest mammals. (Hæckel: *Anthropogenie*).

2. Parallelism of all embryonic series. — Lower forms arrested at earlier stages. — The parallelism suggests descent from common ancestors.
3. Parallelism with geological succession. — Earlier geological types were comparatively embryonic.
4. Parallelism with the morphologically graduated series.
5. An identical order of succession three times occurring. — The first *ontogenetic* and rapid. — The second *palæontological* and slow. — The third *taxonomic* and simultaneous.
6. Embryological history proves that transition by material continuity, from term to term of this succession, is a *fact*. — If a fact in the embryological series, it is probably a fact in the almost identical palæontological and taxonomic series. — The derivation of species by material continuity must therefore be admitted as a general law of nature.

L. EVOLUTION THEORIES.

[Authorities as in Lecture XLIX].

I. Necessary Discriminations in the discussion of Evolution.

1. Is a universal Method of Evolution a *fact* in nature?
2. What are the *conditions* under which an evolution arises?
3. What are the *instruments* and *agencies* for effecting it?
4. What is the *efficient cause* employing the agencies, under the requisite conditions, in producing the fact?
5. These discriminations often overlooked. — The Fact sometimes regarded the ultimate goal of science. — Conditions often regarded a full explanation. — Instruments or agencies often set down as "true causes."

II. Suggestions recorded in the history of Science.

1. As to the Fact. — A frequently recurring doctrine in all ages. — Always met with denials, under the impression that it precludes divine agency.
2. As to the Conditions.
   (1) Modes of the organism.
   (*a*) Inheritance, or transmission of identity. — Centripetal.
   (*b*) Variability, or capacity for change. — Centrifugal.
   (*c*) Prolonged embryonic development. (*Vestiges of Creation*).
   (*d*) Acceleration of development. (Hyatt, as in Lect. XLIX).
   (*e*) Acceleration and retardation of development and growth. (Cope: ***Method of Creation***; ***Origin of Genera***).
   (*f*) Repetitive addition. (Cope: ***Method of Creation***).
   (*g*) Relation to grade of organ or animal. — Cope's "grade influence."
   (*h*) Frequency of exercise. — Equivalent to "use and effort," (Cope), and

"use and disuse," (DeMaillet, Lamarck, Darwin). — Includes "animal motion," suggested by Cope as "cause of animal evolution." (Cope, *P. Amer. A. A. Sci.*, Aug., 1877; *Penn Monthly*, Jan. 1878; *Origin of the specialized teeth of Carnivora*, Am. Nat., Mar. 1879). — This not a cause, since whatever change ensues is caused directly (instrumentally) by the physiological action.

(2) Modes of the environment. — Determining the "struggle for existence." (Darwin: *Origin of species*).

(*a*) Physical surroundings. — (DeMaillet: *Telliamed*; Lamarck: *Philos. Zool*).

(*b*) Competition with fellow-beings.

(*c*) Extermination of unfittest. — Whereby "fittest," *i. e.* best, survive, to continue the species and perpetuate acquired modifications. — The characteristic conception of "Darwinism," which thus leaves all *causation* of variation untouched.

3. As to instrumentalities and agencies.

(1) Reproductive activities. — Normal. — With saltative progress. (Huxley). — *Parthenogenesis*. (Kölliker).

(2) Influence of enviroment. — This a misapprehension.

(3) Physiological activities, organizing material into forms correlated to the environment. — The "growth-force" of Cope.

(4) Inherent conation toward certain modifications of structure. (Lamarck). — Hardly distinguishable from the coördinative force in physiological work. (See next point).

(5) Intelligent selection. (Cope: *Method of Creation*, 29; *Consciousness in Evolution*, Penn Monthly, Aug., 1875. Compare *Origin of the Will*, Penn Monthly, June, 1877).

(*a*) Automatic or unconscious. — A directive influence exerted upon physiological activities.

(*b*) Voluntary or conscious. — Choice of means by which the animal seeks its own well-being. — Part origin of "struggle for existence."

4. As to causes.

(1) Environment, Natural Selection, Use, etc. — These not real causes, but subcauses. — *Environment* only the condition of a certain kind of physiological activity. — *Natural Selection* only the outcome or remainder, after active cause has made certain subtractions. — *Use* only the condition of more intense physiological action in certain organs.

(2) Inherent tendency to improve or change. — Either coöperative or all-underlying and all-conditioning. — In either case, only an effect which conditions other effects.

(3) The Unknowable. (Spencer: *First Principles*, etc).

(4) A Supernatural Power.

(*a*) The real cause is something which cannot be construed as an effect.

(*b*) It acts *in the organism*, through physiological processes, and not at a distance, in the environment.

(*c*) It acts with discernment, cognizing a certain correlation as an end, and directing the operations of life toward that end. — Cognition implies *intelligence;* direction, *will* and *motive* for willing; the cause is therefore, a personality.

(*d*) The cause is not the animal or plant in which the modification takes place. — Nor any other animal. — It is, therefore, a supernatural Cause.

2. Theories are based principally on views in reference to conditions and instrumentalities, and the scope of application of the principle of evolution.

III. Conspectus of Theories of the Origin of Species.

1. Immediate Creation. (Material Discontinuity).

(1) In single Pairs, ... { *Linnæus, Cuvier. Popular Opinion.*

(2) In Colonies, ... *L. Agassiz, etc.*

2. Mediate Creation or Derivation. (Material Continuity or Evolution).

(1) Through a Force which is a mode of the Unknowable. . . . *Spencer.*

(2) Through so-called external influences or forces acting on the generative system.

(*a*) Physical surroundings. (Transmutation). . . . . *De Maillet*

(*b*) The same and conflicts of individuals (Natural Selection) with use and disuse.

(*aa*) Embracing the psychic nature of man.

(*aaa*) By insensible gradations (Variative). . . *Darwin, Haeckel.*

(*bbb*) With occasional leaps (Saltative) and with a molecular selection. . . . . *Huxley.*

(*bb*) Excluding the body and mind of man, ... *Wallace.*

(3) Through an internal force, conditioned by the environment, and by use and disuse.

(*a*) An inherent nisus toward improvement. (Conative-variative). { *Lamarck. St. Hilaire.*

(*b*) Genetic processes exclusively. (Filiative).

(*aa*) Prolonged embryonic development. (Variative-filiative). "*Vestiges.*"

(*aaa*) Heterogeneous generation. . . . . *Kælliker, Ferris.*

(*bbb*) Homogeneous generation. . . . . *Parsons, Owen.*

(*c*) An immaterial force, genetic processes being the instrument. Saltations admitted.

(*aa*) Excluding the psychic nature of man. . . . *Mivart, Nægeli.*

(*bb*) Including the psychic nature of man.

(*aaa*) Through ordinary generation. . . . . *Huxley.*

(*bbb*) Accelerated development, ... *Hyatt.*

(*ccc*) Accelerated and retarded development. . . . . *Cope.*

IV. Conclusions eliminated.

1. Evolution is the designation of a general method employed in nature for the effectuation of results. — "Development" employed in nearly the same sense.

2. "Darwinism" is the designation of a particular theory of the instrumentalities by which the evolution is effected. — Therefore not synonymous with evolution. — May be a false or insufficient doctrine, while evolution is a true one. — Cannot, by any means, claim to be an adequate explanation of the phenomena of organic life.

LI. PRIMITIVE MEN,

THEIR ETHNOLOGY, AFFILIATIONS AND DISPERSION.

A. WINCHELL: *Preadamites*, 8vo., Chicago, 1880, ch. vi, x, xi, xiv, xix-xxv; O. PESCHEL: *The Races of Man*, N. Y., 1876; P. TOPINARD: *Anthropology*, London, 1878; C. VOGT: *Lectures on Man*, London, 1864.

I. The terms Archæology, Ethnology and Anthropology. — Prehistoric Anthropology to be investigated on the same basis as extinct life in general. — The Archæological data discussed in Part I, (Lecture XXII).

II. Primitive Types of Mankind.

2. Existing races of men. (Peschel).
   (1) The Black Races.
      (*a*) Australians and Tasmanians. — (*b*) Papuans and Negritos. — (*c*) Hottentots and Bushmen. — (*d*) Negroes.
   (2) The Brown Races.
      (*a*) Mongoloids: Malays, Chinese, Altaians, Japanese, Americans.
      (*b*) Dravidians.
   (3) The White Race or Mediterraneans.
      (*a*) Hamites. — (*b*) Semites. — (*c*) Japhetites or Aryans.
2. Affinities among ethnic types. — Gradations. — The lower not descended from the higher.
3. The primitive races low in rank. — Australians probably approximate the earliest men. — Higher races later in appearance.

III. Hypothetical continent of Lemuria.

1. Evidences of its former existence.
   (1) Zoölogical. — Lemurs. — Birds. — Men.
   (2) Botanical. — Palms.
   (3) Geological. — Shoals in Indian Ocean. — The entire area in process of subsidence.
2. Here was perhaps the cradle of mankind.

IV. Dispersion of Mankind from Lemuria.

1. Primordial bifurcation of the human stock. — Australian and African stems. — Why not assigned to distinct origins.
2. Dispersion of the Australian branch.
   (1) Australians. — Connection with India. — The Tasmanian differentiation.
   (2) Papuans. — Retral movement to the Andamans. — Divergence to Luzon, Formosa, and perhaps Japan. — Melanesian expansion. — Oceanic improvement of the type.
3. Dispersion of the African branch. (Ulotrichs).
   (1) The Hottentot type. — Moved from eastern equatorial Africa.
   (2) The Negro type. — Kaffir Bantus drove Hottentots southward. — The Soudans spread westward.
   (3) Many Africans not of these races.
4. Rise and dispersion of Mongoloids.

(1) Malayan stem. — Regress to Madagascar. — Pacific expansion. — Micronesian type. — Polynesian type. — Extreme eastward advances.
(2) Thibeto-Burmese stem.
(3) Chinese stem. — Primitive seat. — Migration.
(4) Altaian stem. — The northeastward stream. — Divergence of Turks, Mandchus, Tunguses, Samoyeds and Ural-Altaics.
(5) Troglodytic stem. — Dispersion in N. Africa and in Europe.
(6) American Sedentes. — Access from Asia. — Their characteristics. — Their dispersion over N. America, Mexico, Central America, Granada, Peru, Chile and Patagonia. — Copper-mining, mounds, mesa-ruins, Mexican and Peruvian civilizations.
(7) American Vagantes. — Contrasted with Sedentes. — Compared with Malays. — Access by Polynesia. — Indications of former continental connection. — Spread over the plains of S. America. — Drove back Sedentes in N. America.

5. Rise and dispersion of Dravidians.
6. Rise and dispersion of Mediterraneans.
(1) Hamitic Family. — Displaced Mongoloids everywhere. — Possessed all Western Asia, N. Africa and Southern Europe.
(2) Semitic Family. — Absorbed Hamites in Asia. — Semitic empires. — Maritime Phœnicians.
(3) Aryan Family. — Asiatic branch. — European branch. — Ultra-Euxine and cis-Euxine streams. — Ulterior ramifications.

LII. THE ANTIQUITY OF MAN.

A. WINCHELL: *Preadamites*, ch. xxvii; SIR C. LYELL: *The Geological Antiquity of Mankind*; J. C. SOUTHALL: *The Recent Origin of Man*, Phil., 1875; *The Epoch of the Mammoth*, Phil., 1878; E. ANDREWS, *A. J. S.*, II, xlv, 180; *Meth. Quar. Rev.*, Dec. 1876, Jan. 1877.

Three aspects of discussion on this question.

I. Epoch of the First Men.
1. No positive data bearing directly on the question.
2. They probably appeared in Tertiary time.

II. Epoch of the Stone Folk of Europe. — Their antiquity long exaggerated. (Haeckel: *Natuerlich. Schœpf.*, 595, *etc*). — Grounds of such opinions.

1. Preglacial remains of other animals mistaken for human remains.
(1) Notched bones found at St. Prest, France, with Pliocene elephant. — Marks made by a contemporary rodent.
(2) Cut bones of Léognan, of Miocene age. — Marked by a carnivorous fish.
(3) Flints in Miocene of Thenay. (*Congr. Internat.*, 1867, 67). — Not artificially produced.

2. Human remains erroneously supposed preglacial.
(1) The Guadeloupe skeletons. (D. 579; C. König, *Phil. Trans.*, 1814, 107).
(2) Human skeleton with Pliocene elephant at Le Puy-en-Velay. (Topinard: *Anthropology*, 436; Caspari: *Urgesch. der Menschheit*, I, 84). — Skeleton *not* in same lava as elephant, but a later lava.
(3) Flints in the gravels of the Somme. — But these gravels prove to be post-glacial.

(4) Human skull from Pliocene of Colle del Vento. (Issel, *Cong. Internat.*, 1867, 75, 156). — The fact not scientifically established.

(5) Human pelvis in a preglacial deposit at Natchez. — The bone fell down from the top of a bluff. (Lyell: *Antiq. Man.*)

(6) Remains in Victoria cave, Eng. (Geike). — The deposits probably not preglacial. (J. Evans, *Add. Geol. Soc. Lond.*, 19 Feb., 1870; *A. J. S.*, III, x, 229–32).

3. Man not preglacial in Europe. (Huxley, *Nature*, 22 Aug., 1878, 448. Comp. Haeckel, *op cit.*, 594). — But he witnessed the decline of the glaciers.

4. Man probably of Pliocene age in California. (J. D. Whitney). — Probably of Mongoloid type.

5. Remoteness of the glacial decline in Europe.

(1) Human history and movements in glacial and preglacial times.

(2) Grounds of belief in high antiquity of glacial epoch.

(*a*) Astronomical hypothesis of glacial periods. (Lect. XLV, V).

(*b*) Cotemporaneousness of man with extinct animals. (Lect. XXII). — Extinctions not necessarily remote.

(*aa*) Gigantic extinct birds of New Zealand and the Mascarenes. (D. 580–1; L. 558–60; *Encyc. Brit.*, 9th ed., iii, 731; A. Milne-Edwards, *Comptes Rendus*, May, 1875; *A. J. S.*, III, x, 233. Comp. A. Günther, *Nature*, 28 July, 1874). — *Rytina Stelleri, Balæna Biscayensis*, Trojan shells.

(*bb*) Species approaching extinction. — Great auk, Labrador duck, capercailzee, great aurochs, sequoia and many familiar species.

(*cc*) Extinctions apparently recent. — Mammoth, Mastodon, (*Am. Nat.*, April, 1879, 269. — Irish elk.

(3) Magnitude of geological changes since man's advent. — Real greatness of those changes.

(*a*) Remoteness in time produces an illusion. — Historic times record great geologic events. — Geographical changes in China. (Pumpelly, *Smiths. Contr.*, 4to., xv, art. iv; Von Richthofen: *China*, 285–7). — Changes in basin of Black and Caspian seas. (W.: *Pread.*, 440 and *ref.*).

(*b*) Retreat of Alpine glaciers. (Tyndall: *Hours of Exercise in the Alps*; W.: *Pread.*, 437–8). — Existing stumps in America. (Lect. XIX, III, 6).

6. Estimates of prehistoric archæologists. — Appearance of Iron in the West 2700 years ago. — Age of Bronze, 2700 to 4000 years. — Age of Polished Stone, 4000 to 6000 years. — Age of Reindeer, 7000. — These results accordant with traditional indications. (W.: *Pread.*, 442).

III. **Epoch of Mediterranean Race.** — Must exceed somewhat the historic antiquity of Egypt. — Era of Menes according to Lepsius, 3892 B. C. — According to Mariette and Lenormant, 5004 B. C.

LIII. ESTIMATION OF GEOLOGICAL TIME.

I. Oppressiveness of Geological Æons.

1. Geological changelessness of some historic spots. — Plymouth Rock. — The Acropolis. — Mont Blanc.

2. Permanence of the aspects of the heavens.
3. Slowness of shore-erosions and of sedimentary processes.
4. Time required for material of a bed of coal.
4. Such facts tend to produce an exaggerated impression of the vastness of geological periods. — We need some comprehensible unit of measure.

II. Cosmical Limitations of Terrestrial past Duration.

1. Age of the Sun's heat. (Sir W. Thomson, *Phil. Mag.*, viii, 1854; *Macmillan's Mag.*, March, 1862; *Address Brit. Assoc.*, Edinb., reprint, *A. J. S.*, III, ii, 286, Oct. 1861; Croll: *Climate and Time*, ch. xxi).

   (1) Meteoric theory of solar heat, (Mayer: *Celestial Dynamics*, Youmans' ed., 261).
   (2) Contractional theory. (Helmholtz, *Phil. Mag.*, xi, 1856; W. Thomson, *Phil. Mag.*, viii).
   (3) Solar heat probably, in large part, a residuum of the primitive temperature. (W., *Sketches*, ch. xxxviii; Croll: *Clim. and Time*, 349, *seq*).

2. Duration of the secular cooling of the earth. — A maximum of 100,000,000 years since commencement of incrustation. (Thomson and Tait: *Nat. Phil.*; Croll: *Clim. and Time*, 335). — Actual calculation results in 80,000,000 years. — Reade demands 500,000,000 years since sedimentation began in Europe. (*Ann. Addr. Liverpool Geol. Soc.*, 1876; *A. J. S.*, 1876, 462).

3. Duration of tidal retardation of earth's rotation. — The investigation not yet made.

III. Calculation based on relative thickness of Sediments. (D., 381, 481, 585).

1. Account cannot be taken of relative energy of geologic forces. — Probably greatest in the world's early history.

2. Maximum thickness of sediments, limestone being multiplied five-fold. (D., 381): Archæan, 230,000 ft.; Palæozoic, 153,000; Mesozoic, 38,300; Cænozoic, 12,800. — Joining palæontological with stratigraphical evidences, **Devonian + Triassic = Jurassic + Cretaceous + Cænozoic.** (Ramsay, *Proc. Roy. Soc.*, No. 152, 1874).

3. The Pyrolithic æon probably as long as the Archæan.

4. Distribution of the Earth's incrusted life-time. (Comp. D., 591).

	Percentages.	*Years.*
Pyrolithic Æon. (Fire-crust),	34.6	34,600,000
Archæan Æon. (Strata),	34.6	34,600,000
Palæozoic Æon,	23.1	23,100,000
Silurian,	15.6	15,600,000
Lower Silurian, (Cambrian),	13.2	13,200,000

	Percentages.	*Years.*
Potsdam Sandstone,	1.9	1,900,000
Rest of Lower Silurian,	11.3	11,300,000
Upper Silurian,	2.4	2,400,000
Devonian,	3.8	3,800,000
Carboniferous,	3.8	3,800,000
Mesozoic Æon,	5.8	5,800,000
Triassic,	1.78	1,780,000
Jurassic,	2.22	2,220,000
Cretaceous,	1.78	1,780,000
Cænozoic Æon,	1.9	1,900,000
Tertiary,	1.5	1,500,000
Post-Tertiary,	0.4	400,000
Glacial,	0.2	200,000
Champlain,	0.2	200,000

5. This result for post-glacial time perhaps too great. — One hundred millions too high an aggregate, and Pyrolithic and Archæan relatively longer than assumed.

IV. Calculation based on Eccentricity of Earth's Orbit.

1. Supposes maximum eccentricity the indirect cause of northern glacial periods. (Lect. XLV, V, 4).
2. Last occurring epochs of maximum eccentricity before 1800 A. D.:— 100,000 years (.0473), 210,000 years (.0575), 310,000 years, (.0424), 750,000 years (.0575), 850,000 years (0747). — Those at 210,000 and 850,000 years the most striking.
3. Croll regards last Glacial Period as extending from 240,000 to 80,000 years ago. (Croll: *Clim. and Time*, 325, 355). — The Miocene glaciation he puts at 850,000 years ago, and the Eocene at 2,500,000 years. (Croll: *op cit.*, 358–9). — These figures apparently too high. — The last mid-glacial epoch perhaps 100,000 years ago. — Then, since decline of glaciers, say 50,000 years.

V. Calculations based on Erosion and Deposition.

1. Gorge of Niagara. (D., 219, 590; L. 14; Hall: *Geol. N. Y.*, iv, ch. xx; R. Bakewell: *Geol.*, 260; J. Marcou, *Bull. Soc. Geol. de France*, II, xxii, 190, 529; Ramsay, *Q. J. G. Soc.*, xv, 1859; T. Belt, *Q. J. Sci.*, April, 1875). — Assuming rate of Erosion uniform.

(1) R. Bakewell, 3 feet per year, 12,300 years.
(2) Lyell and Hall, 1 foot per year, 35,000 years.
(3) E. Desor, .03 foot per year, 1,232,000 years.
(4) J. Marcou, .52 foot per year, 71,000 years.

(5) T. Belt, 0.1 foot per year, 200,000 years for whole gorge, but only 20,000 for that below the whirlpool. — The remainder of the gorge, and all the old one, being considered preglacial. — Last result accords best with limits of time at our disposal for terrestrial history.

2. Gorge of Mississippi, at St. Anthony. (N. H. Winchell, *Q. J. G. Soc.*, Lond., Nov. 1878, 880). — Rate from 1680 to 1856, 5.15 feet per year; time from Fort Snelling, 8202 years. — This a post-glacial erosion.
3. Deltas of rivers.
   (1) The Mississippi delta about 5000 years. (Humphreys and Abbot, *Hydraulics of the Miss.*, 1861. Comp. L. 28).
   (2) The Nile delta, 6350 years. (De Lanoye: *Rameses the Great.* Comp. L. 28).
4. Terraces of Lake Michigan. (E. Andrews, *Trans. Chic. Acad. Sci.*, ii; Southall: *Epoch of the Mammoth*, ch. xxii). — Total time since Glacial Period, 5300 to 7500 years.
5. General continental erosion. (L., 10–11; Croll: *Clim. and Time*, ch. xx; Geikie, *Trans. Geol. Soc. Glasgow*, iii; Jukes and Geike: *Man. Geol.*, ch. xxv; A. Tylor, *Phil. Mag.*, 1850). — Subsidence in basin of Danube, one foot in 6846 years; of Mississippi, 4640; of Nile, 4723; Ganges, 1751; Rhone, 1528; Hoang-Ho, 1464; Po, 729 years.

LIV. LIMITATIONS OF THE EXISTING ORDER.

I. Meaning of Change in the natural World.

1. It implies a beginning.
2. It implies an end.
3. The idea of endless cycles physically absurd. (W., *Sketches*, ch. xxxv). — Perpetual motion equally impossible in human and in the cosmic mechanism. — All force seeking a state of equilibrium. — Finite time suffices for the accomplishment of any work, however vast.
4. Recognized principle of degradation of physical organisms. — Dissipation of energy. (W., *Mich. Jour. Educ.*, Aug. 1860, 273; *Ladies' Repos.*, Cin., Jan., 1864; *College Courant*, New Haven, Jul. 12 and 17, 1869; *Sketches of Creation*, 1870; Sir. W. Thomson; Helmholtz; Spencer: *First Prin.*, 450, *etc*).

II. Ultimate tendencies of Terrestrial Erosions. (Lect. XXVII, XXVIII; W., *Sketches*, ch. xxxvi).

1. Wastage of soils. — Disappearance of vegetation and aridity of climate. — Sinking of river-channels. (D., 641–2). — Filling of lakes and seas. — Transfer of elevations to deltas and sea-bottoms. — Great American Desert. (Wheeler, *Prelim. Rep.*, 1871, 20; Powell: *Colorado*).

2. Growth of Delta of Mississippi river. (D., 651–2; Humphreys and Abbot: *Hydraul. Miss*,, 141, 418, *etc*). Total annual contribution, one square mile 268 feet deep. — Annual advance of delta, 338 feet. — Inevitable destruction of the upland.
4. Lowering of continental surfaces.
   (1) Sundry estimates. (Lect. XXVIII, LIII).
   (2) Relative masses of continents and oceans.
      (*a*) Mean height of land. (Krümmel, *Gottingen Acad.;* G. Leipoldt, *Petermann's Mittheilungen*, April, 1875; *Nature*, 15 April, 1875; *A. J. S.*, III, ix, 482; *Nature*, 3 Feb., 1879, 348-9). — Europe, 300 m.; Asia and Africa, 500 m.; America, 330 m.; Australia, 250 m.; mean, 426 m., or 0.0566 mile. — Surface ratio of land to water, 1:2.75. — Ratio of volume of land to water, 1:22.4.
      (*b*) Continents above sea-level transferred to sea-basin would raise the sea 112.4 m., or 368.2 ft. above the land. — This doctrine enunciated by Buffon. (*Theorie de la Terre.*) — But denounced by the Sorbonne. (Lyell: *Prin.*, 41; Buffon: *Hist. Nat.*, tome v, ed. de l'Imp. royale, Paris, 1769.

III. Progressive Terrestrial Refrigeration. (Lect. XLI).

IV. Absorption of Sea And Atmosphere. (Lect. XLI, V.2). — Observed secular desiccation of the continents. (J. D. Whitney, *Amer. Nat.*, x, 513, Sep., 1876).

V. Coincidence of Axial and Orbital Periods of the Earth. (Helmholtz: *Interaction Nat. For.*, Youmans' ed., 243). — Six months insufferable heat and six months insufferable cold.

VI. Solar Refrigeration. (Lect. XLI). — Vast emission of heat. — No known source of adequate supply.

VII. Final Aggregation of Matter. (W., ch. xxxix; Spencer: *First Prin.*, 480, *seq.*; Fiske: *Cosmic Philos*).

1. Conditions of Stability of our System. (Laplace). — The planets solid and their motions *in vacuo*. — Neither condition fulfilled.
2. A resisting medium in space. (B. Stewart: *Conservation of Energy*, 96; Fiske: *Cosmic Phil.* Also, Spencer, Cousin, etc.).
3. Shortening of periods of rotation. — Encke's comet. — The fact denied. — Illustration from meteoroids in our atmosphere. — Inevitable precipitation of planetary matter.
4. Process of aggregation in other systems.

VIII. Glimpses Beyond.

1. Question of final aggregation of all matter. — The result inconceivable.
2. There must be a reorganizing principle active in nature. — But the forces of matter incapable of effecting a cosmic resurrection.
3. Cycles of matter. (W., ch. xl).

LV. WORLD-LIFE.

A. WINCHELL: *Geology of the Stars*, Half-Hour Recreations in Popular Science, 279-82; ENNIS: *Origin of the Stars*.

I. General Cosmic Morphology.

1. The deepest principle of change in cosmic existence is expressed by the word *cooling*. — Other activities come into play concomitantly.
2. The three great cosmic forces are *heat* and atomic and molar *attractions*.
3. A world's life-time is but a progressive cooling, with its incidents and consequents. — It passes successively through all the phases and stages known to cosmogony.
4. Cosmic life-times have begun at different epochs, and proceed at different rates. — Probably beginning and ending continuually. — Hence, contemporary cosmic existence, analogously to the kingdoms of organic life, presents a simultaneous panorama of a world's life-time. — The taxonomy of the heavens is therefore a cosmic embryology and a cosmic palæontology. (Lect. XLIX, IV, 5).

II. Nebular Stage.

1. Diffused Phase or Cosmical Dust. (Lect. XLII). — Cosmic atoms gathering, condensing and developing heat. — An antecedent phase of matter supposable, in the form of a continuous, cold, or heated gas. (Ennis: *Origin of the Stars*, sec. xvi). — But the conception not yet correlated to the normal nebulous condition.
2. Normal Nebular Phase. — Mineral mist floating in a gaseous medium. — Spectrum of one, two or three bright lines. (Lect. XLII, VI, 4). — *Some of the irresolvable nebulæ.*
3 Continuous Fire-mist Phase. — Mineral mist increased in quantity, but the mass remaining homogeneous and mostly gaseous. — Spectrum of bright lines superposed on an extremely faint, continuous spectrum of scarcely appreciable breadth. — *Certain irresolvable nebulæ;* also, *a few "stars."*

   Annulations perhaps take place in this phase. The primitive nebula is resolved into solar nebulæ, in which other annulations succeed. — Annular, and probably spiral and curved nebulæ. — Saturnian rings persisting like a preserved embryo.
4. Discontinuous Fire-mist Phase. — Segregation and accumulation around local nuclei, without annulation. — Fire-mist or photospheric matter still in small proportion to gaseous. —

Bright line spectrum superposed on a faint continuous spectrum. — *Certain resolvable nebulæ.* — Compare nebula in Draco.

III. Stellar Stage.

1. Nucleating Phase. — Increasing amount of photospheric matter. — Nuclear condensation apparent. — Sun systems and planetary segregations past the phase of annulation. — Bright lines over a continuous spectrum. — *Planetary Nebulæ* and *Nebulous Stars.*
2. Nucleated Phase. — Liquid precipitate increased. — Temperature and luminosity so diminished that the absorbent capacity of the still gaseous atmosphere just equals the emissive power of the nucleus and photosphere. — Spectrum continuous. — Certain *star clusters* and most *resolvable nebulæ.*
3. Sirian Phase. — Atmosphere of great depth and tension. — Absorbent capacity exceeds emissive. — Spectrum of dark lines of extraordinary breadth. — *White stars.*
4. Arcturan Phase. — Atmosphere diminished in depth and tension. — Spectrum the normal solar spectrum. — *Yellow Stars.*
   (1) Some fixed stars in the last two stages the centres of cosmic systems.
   (2) Some have their attendant worlds still luminous.
      (*a*) Sirius a sun with four still luminous *planets.*
      (*b*) Procyon, Rigel, Aldebaran, Arcturus, Antares, Zeta Cancri, etc., have each one or more.
      (*c*) Some of these companions have still smaller attendants, as Mu Lupi, Eta Lyræ, Xi Cancri, 12 Lyncis, Theta Orionis. — These are still-luminous *satellites.*
5. Solar Phase. — Photosphere thinned to point of eruption by upward vortical movements. — Maculation by condensation of the cooled vapors. — Incipient variability. — *Our sun.*
6. Variable Phase. — Photosphere periodically darkened by the great amount of macular matter floating on photosphere. — Approaching total liquefaction. — *Periodic* and *Irregular Stars.* — Their periods from a few hours to 500 days, and range of brightness from fourth to ninth magnitude. (Argelander in Humboldt's *Cosmos*, iii).
7. Molten Phase. — Photospheric matter exhausted. — A molten globe. — Spectrum continuous. — Some *star clusters* and *resolvable nebulæ.*
8. Incrustive Phase. — Primitive crust. — The light ruddy. — Incipient darkening. — Spectrum of dark lines, but giving the *ensemble* of vaporosity. — *Red Stars.*

9. Eruptive Phase. — Crust darkened, but disrupted at intervals, giving spasmodic luminosity. (Lect. XXXIX, IV). — Spectrum returns to vaporous or other earlier indications. — *Temporary Stars.* (Ennis: *Origin of the Stars*, 123–8).

IV. Planetary Stage.

1. Jovian Phase. — The stormy condition. (Lect. XXXIX, IV–VI).
2. Terrestrial Phase. — Culmination of organic career. — Movements of atmosphere comparable with those of solar photosphere. — Earth and some satellites of Jupiter and Saturn.
3. Martial Phase. — Planetary senescence. — *Mars* and *some satellites* of older planets.
4. Retarded Rotary Phase. — Work of tidal retardation far advanced. (Lect. LIV, V). — *Moon, Mars* and some *older satellites.*
5. Lunar Phase. — Planetary death. (Lect. XLI, II, 2, V). — *Moon* and some *older satellites.*

V. Unity of Cosmical Phenomena.

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